WIN A TELSCOPE WORTH £220!

3 FREE eBOOKS! WORTH £30

WORLD'S GREATEST CASTLES ANCIENT CIVILISATIONS WORLD'S GREATEST CITIES

HOW IT WORKS

10 MILESTONES OF SPACEFLIGHT

"IT'S THE FIND OF A LIFETIME" MEET A REAL-LIFE FOSSIL HUNTER

HOW CORONAVIRUS TEST SITES WORK

PROTECTING CROPS FROM BUG INVADERS

BEHIND THE SCENES OF THE LONDON MARATHON

DIGGING FOR DINOSAURS

How YOU could make the next incredible fossil discovery

WE LOOK INSIDE AN ALL-ELECTRIC CAR

+ WHY WE BREATHE SOLAR-POWERED HOMES HUGE HIPPO JAWS

FUTURE
ISSUE 143


WAR THUNDER
New? GET YOUR FREE BONUS
Experience realistic air battles in War Thunder!
Battle in more than 1700 different aircraft, tanks and ships from the 1930s to present day- Including more than 20 different models of the Legendary Supermarine Spitfire! Control any vehicle using your mouse and keyboard, gamepad or joystick. Now available for FREE on PC, Playstation 4 and Xbox One. Get your free bonus now!
WARTHUNDER.COM/FLY
XBOX ONE
PS4
Windows
STEAM
Mac
oculus
VIVE
12
www.pegi.info

WELCOME

The magazine that feeds minds!

© Getty

"I videoed myself picking it up and posted it online. I knew it was from a dinosaur"

Digging for dinosaurs, page 20

Meet the team...

Nikole
Production Editor
Venice, the famous 'floating city', is well known for its canals. Explore how its amazing architecture was built on page 28.

Scott
Staff Writer
Each year millions of crop plants are destroyed by insects. Discover the ways farmers can safeguard our food on page 32.

Baljeet
Research Editor
How do magnets work, how can we magnetise metals and where can we find them around our homes? Page 40 has all the info.

Duncan
Senior Art Editor
With climate change a looming threat, electric cars look to be the future of driving. Peek inside the all-electric Honda e on page 54.

Ailsa
Staff Writer
How have past missions enabled us to further explore space? Look at major milestones of spaceflight on page 60.

You're in good company if you've ever dreamed of stumbling upon a dinosaur skeleton, or of breaking open a rock to discover an impression of past life, hidden for millions of years. But there are only a handful of locations in the world where that fantasy is a real possibility. In our cover feature on page 20, we've explored how ancient animals and plants are fossilised in different ways. We've also spoken to a scientist and professional fossil hunter who recently found a new species of dinosaur on a British beach. Discover what you can do to increase your chances of finding fossils, and the best places to go to find them. Enjoy the issue!

Ben Editor

FOLLOW US...
howitworksmag
How It Works magazine
@HowItWorksmag

For exclusive **HIW** news and offers, sign up to our mailing list **howitworksdaily.com/newsletter**

CONTENTS

AR ZONE!

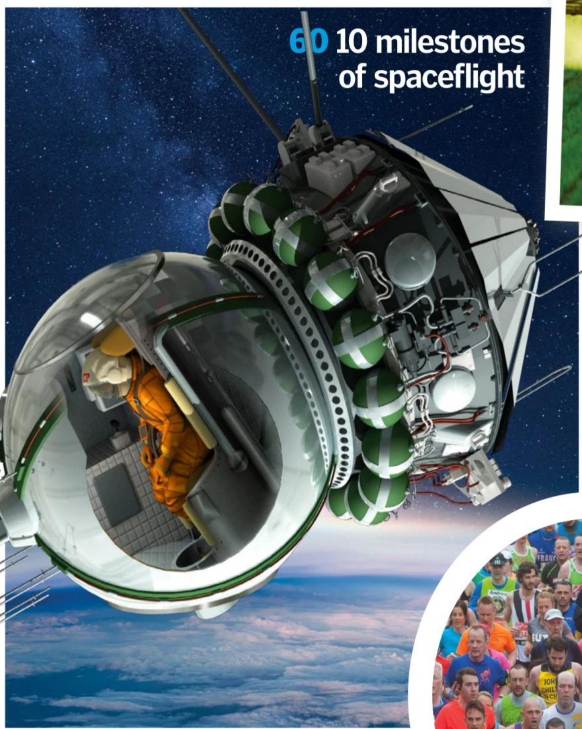
Scan the QR code with your device's camera or download a free QR code reader app. Many iPhone and Android devices include a QR reader

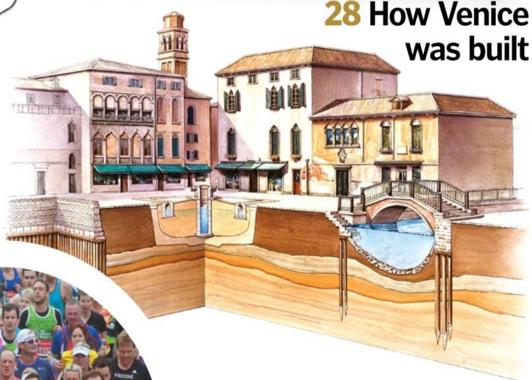
When you see the AR ZONE! logo at the top of a page, use your phone to scan the QR code, which looks like this

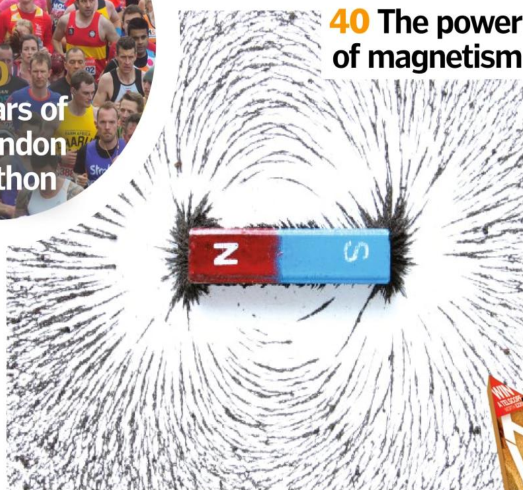
Hold your mobile device over the image and watch it come to life! Your device needs to be connected to the internet for this to work

HOW THE AUGMENTED REALITY WORKS

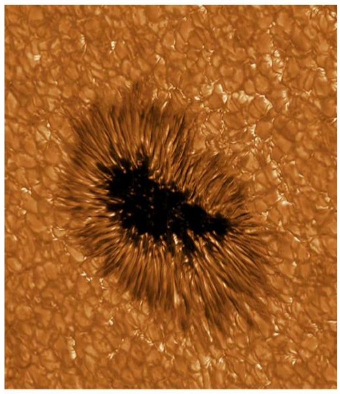
After being launched by the QR code, the app reads anything you point your device's camera at 30 times a second, searching for distinctive shapes we've trained it to recognise. When it sees a familiar picture, it overlays the augmented-reality 3D image we've previously uploaded on your screen.







REGULARS



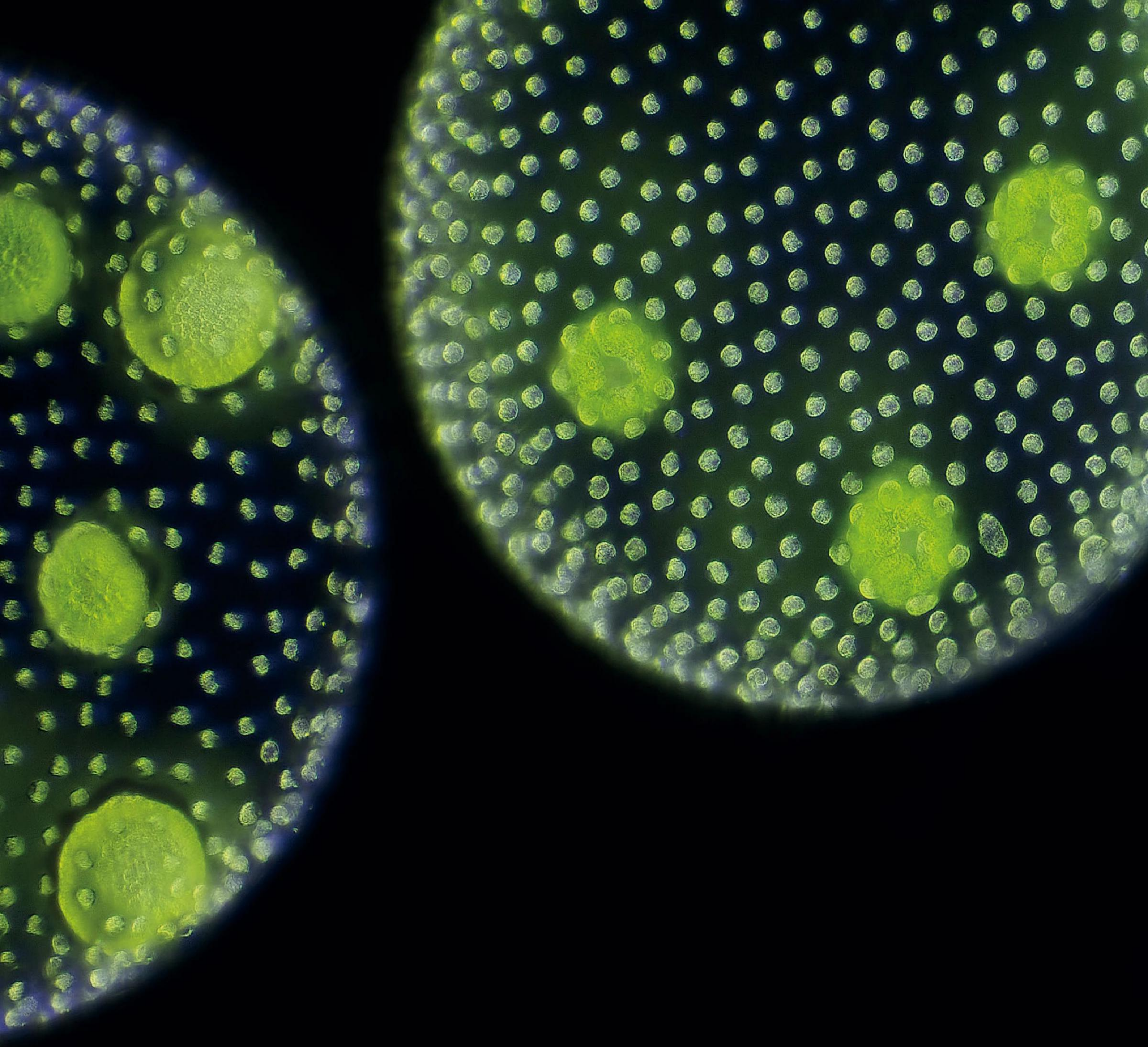
SUBSCRIBE NOW!

Go to page 18 for great deals

THE DOOR TO HELL

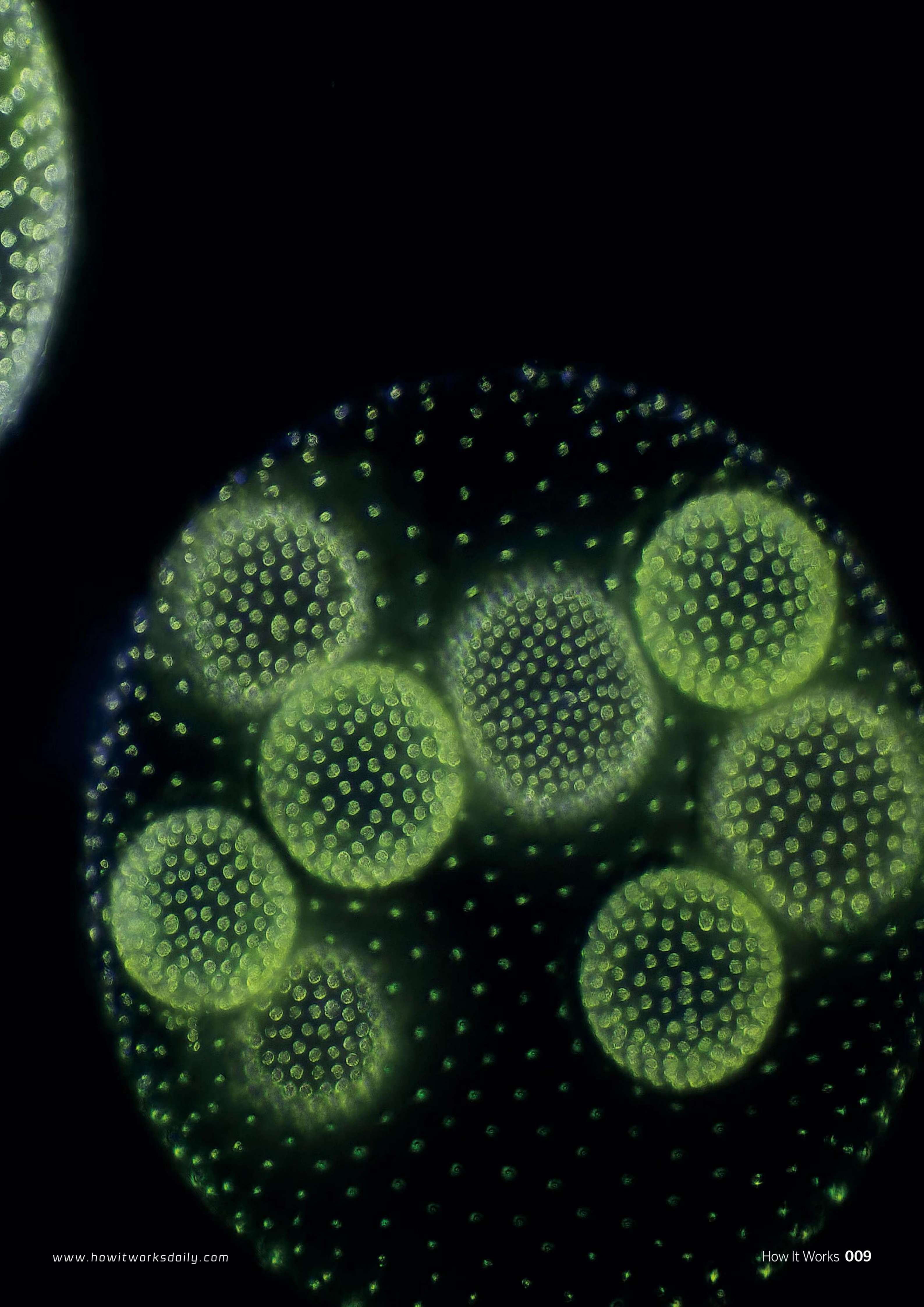
Found burning in the barren wasteland of the desert of northern Turkmenistan, Central Asia, is a fiery pit called the Darvaza gas crater, commonly known as the 'Door to Hell'. This hellish 30-metre-deep crater is believed to have been burning since 1971, although how it collapsed and was ignited remains a mystery. What we do know is that the crater remains alight due to a large amount of methane gas that's being naturally pumped at high pressures from below the desert surface. Turkmenistan sits on the sixth-largest reservoir of natural gas in the world, and some geologists believe that there is enough fuel beneath the crater to allow the fire to rage for another 20 years.

© Getty



INSIDE A VOLVOX COLONY

Volvox are free-floating algae that live in freshwater systems. As single cells, volvox are equipped with two long, tail-like filaments called flagellum which allow them to swim. These individual cells group together to create volvox colonies and form a sphere, as shown in this image. Colonies can be made of up to 60,000 cells and move as one using their outward-facing flagellum. Each individual volvox can produce its own food through photosynthesis and uses photosensitive structures called 'eyespots' – seen as small green specks – to detect the best places for light. The internal spheres are daughter colonies which are filled with reproducing volvox and will eventually break away as their own colony.



PLANET EARTH

A supernova sparked mass extinction 359 million years ago

Words by Mindy Weisberger

A global extinction event that occurred around 359 million years ago may have been triggered by the death blast of a distant star. Towards the end of the Devonian Period, 416 million to 358 million years ago, there was a mass extinction known as the Hangenberg event; it wiped out armoured fish called placoderms and killed off approximately 70 per cent of Earth's invertebrate species. But scientists have long puzzled over what caused the event.

Recently preserved plant spores offered clues about this ancient extinction. Fossil spores spanning thousands of years at the boundary of the Devonian and the Carboniferous periods showed signs of damage caused by ultraviolet (UV) light. This find suggested that a cataclysmic event had caused a long-lasting disruption of Earth's ozone layer, which shields the planet from harmful UV rays. Scientists proposed that a likely candidate for this blast of UV light could be one or more supernovae that exploded within 65 light years of Earth.

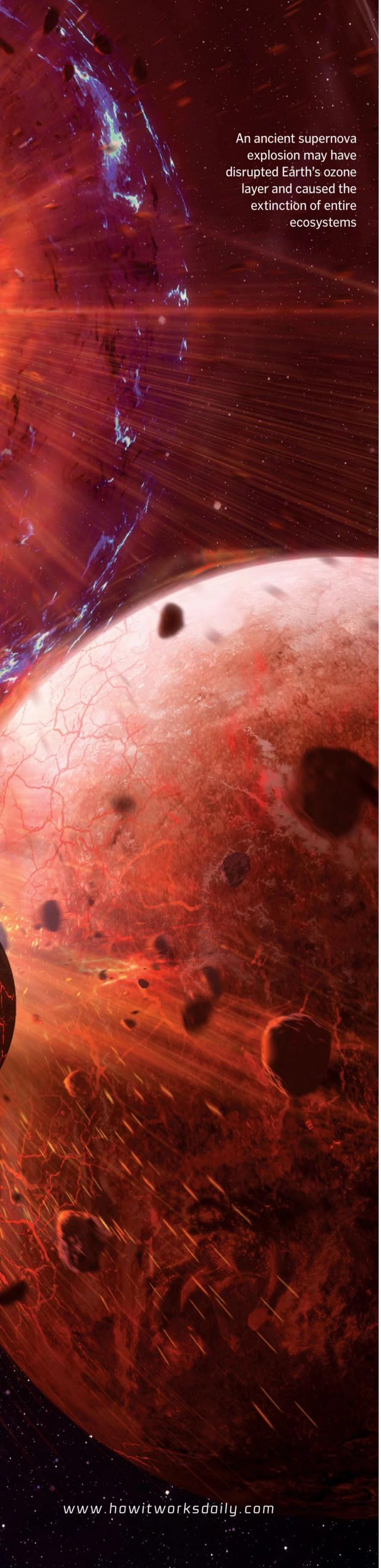
Climate change and extreme volcanic activity can also damage the ozone layer, but evidence in the geologic record at the end of the Devonian Period couldn't clearly link the ozone depletion to a global disaster that originated on Earth.

When stars die they release blasts of UV light, X-rays and gamma rays. If a supernova is close enough to Earth, these rays can shred the ozone layer, exposing Earth to unfiltered UV light from the Sun and harming life on the planet's surface. However, this damage is typically short-lived. Its effects fade after a year or so, "and after a decade, Earth restores its ozone," said Brian Fields, a professor in the department of astronomy at the University of Illinois at Urbana-Champaign.

But that initial bombardment is just the first stage of the damage a neighbouring supernova can inflict. "Later the supernova blast slams into the Solar System. The blast acts as a particle accelerator, and Earth is bathed with an intense rain of high-energy particles," which are known as muons, Fields said. Not only does this blast strip away Earth's ozone layer again, muons then irradiate Earth's surface and penetrate deep underground and into the oceans. "These will damage life, and the cosmic rays will linger for many thousands of years – up to 100,000 years," Fields said. If a nearby supernova – or more than one – shredded Earth's ozone layer, that could explain the UV damage found in Late Devonian spores and pollen over millennia.

"Work by my co-authors and others has shown that a supernova about 25 light years away would lead to biological cataclysm… a true mass extinction," Fields said. "For context, the nearest star today is four light years away," he added. As the Hangenberg extinction was less severe than other mass extinctions in Earth's history, it's estimated that the Devonian supernova would have exploded about 65 light years away.

However, there is not yet a potential candidate for a star in this range that died 359 million years ago. The good news is that you don't need to worry about a supernova upending life as we know it – at least not anytime soon.



An ancient supernova explosion may have disrupted Earth's ozone layer and caused the extinction of entire ecosystems

Stone pinnacles jut out of the forest in Mulu National Park in Malaysia

© Getty

PLANET EARTH

Stone forests formation shown with rock candy

Words by **Stephanie Pappas**

The stunning, razor-sharp spires of stone forests can form in deceptively simple conditions, a sugary new experiment has found. Using sticks of candy, researchers discovered that cylindrical shapes can naturally sharpen into points in still water as they dissolve, with no complicated flow required. This phenomenon could explain why sharp stone pinnacles are often found where easily dissolvable limestone rock predominates.

"We found the simplest recipe for how to make one of these pinnacles," said Leif Ristroph, an experimental physicist and mathematician at New York University.

The recipe was simple indeed. Ristroph and his team cooked up hard candy, like a lollipop, in the shape of a cylinder with a domed top. They stuck the candy upright in a tank of water and simply let it dissolve. You might imagine that the candy would simply shrink away, staying more or less the same shape. But that's not what happened. Instead it gradually sharpened into a point as it dissolved, and these points could become quite sharp.

The next step was to do the math to figure out why this sharpening effect occurred. As the candy dissolves, the water directly next to the sugar column becomes laden with sugar. This makes it heavier than the surrounding water. This sugar-laden water sinks downwards, almost like a skin sloughing off the candy.

This sinking means that the dissolving candy essentially creates its own flow. Fresh water flows in from the sides, only to become laden with sugar itself and sink. The flow is what sharpens the candy into a point.

Limestone and other dissolvable rock are more complex than simple sugar, though, and there are likely other factors that help shape the stone forests found around the world. Rock chemistry, loose sediment and winds likely play a role. But the stone forests largely form while submerged under water, and the simplicity of the candy experiment helps explain the basic process. "Our choice of materials here, as pure water and pure candy, it is purposefully clean so we can understand it in terms of the fundamentals," Ristroph said.

SPACE

3,200-megapixel camera snaps record-breaking first photos

Words by Mike Wall

The camera core for the future Vera C. Rubin Observatory has snapped its first test photos, setting a new world record for the largest single shot by a giant digital camera.

The imaging sensor array, which comprises the focal plane for Rubin's SUV-sized digital camera, snapped the 3,200-megapixel images during recent tests at the Department of Energy's (DOE) SLAC National Accelerator Laboratory in California. SLAC stands for Stanford Linear Accelerator Center, the facility's original name.

The photos are the largest single-shot pictures ever taken, and are so big that showing just one of them at full size would require 378 4K ultra-high-definition TVs. The resolution is so good that a golf ball would be visible from 25 kilometres away.

The first images don't show distant golf balls, however. The SLAC team that's building Rubin's Legacy Survey of Space and Time (LSST) Camera focused on nearby objects, including a Romanesco broccoli, whose intricately textured surface allowed the sensors to strut their stuff. "Taking these images is a major accomplishment," said SLAC scientist Aaron Roodman. "With the tight specifications, we really pushed the limits of what's possible to take advantage of every square millimetre of the focal plane and maximise the science we can do with it."

Like the imaging sensor in your smartphone camera, the LSST Camera's focal plane converts light emitted or reflected by an object into electrical signals that generate a digital photo. But the LSST Camera's imaging core is far larger, more complex and more capable than any consumer electronic product. The newly tested focal plane is more than 0.6 metres wide and harbours 189 individual sensors, or charge-coupled devices (CCDs). The CCDs and their associated electronics are housed in 21 separate 'rafts', subunits that are about 60 centimetres tall, weigh about nine kilograms and cost up to $3 million (£2.3 million) apiece.

"The camera should be ready for final testing by next year"

The rafts were built at the DOE's Brookhaven National Laboratory in New York and then transported to SLAC. In January 2020 the SLAC team finished slotting the 21 sensor-bearing rafts, plus another four speciality rafts not used for imaging, into their assigned places in the focal-plane grid, an exacting and nerve-wracking process that took about six months.

The rafts are packed incredibly tightly to maximise the focal plane's imaging area; the gap between CCDs on neighbouring rafts is less than the width of five human hairs. And the sensors are fragile, cracking easily if they touch one another.

The newly released images are part of extensive, ongoing tests designed to vet the focal plane, which has not yet been installed on the LSST Camera. That integration step will happen in the next few months, as will the addition of the camera's lenses and other key components, if all goes according to plan. The camera should be ready for final testing by the middle of next year. It will then be shipped to the Chilean Andes, where the Vera C. Rubin Observatory is being built.

The complete focal plane of the LSST Camera is more than 60 centimetres wide and contains 189 individual sensors that will produce 3,200-megapixel images

The ice near the Shirase Glacier (lower left corner) in East Antarctica

© Alamy

PLANET EARTH

Scientists discover the fastest melting spot in East Antarctica

Words by Brandon Specktor

Researchers have discovered a deep underwater trough in Antarctica that could spell doom for one of the continent's vulnerable ice shelves. Located below the Shirase Glacier in East Antarctica, the trough appears to be funnelling warm ocean water directly against the base of the glacier's ice shelf, known as the Shirase Glacier Tongue, which juts out into the nearby bay like a frosty peninsula.

This pipeline of warm water is causing the tongue to melt from the bottom up at an alarming rate. Due to this the base of the Shirase Glacier Tongue is losing 7 to 16 metres of ice per year, potentially making it the fastest melting region in East Antarctica.

"This is equal to – or perhaps even surpasses – the melting rate underneath the Totten Ice Shelf, which was thought to be experiencing the highest melting rate in East Antarctica at a rate of 10 to 11 metres per year," said Daisuke Hirano, an assistant professor at Hokkaido University, Sapporo, Japan.

The Shirase Glacier is part of the Antarctic ice sheet, a vast, frozen reservoir that contains more than 60 per cent of the world's freshwater. Climate change is causing the ice sheet to melt at a quickening pace, melting six-times faster today than in 1992 and pouring more than 453 billion tonnes of water into the sea every year.

If the entire ice sheet melts, it could raise global sea levels by 60 metres, but even a rise of 60 centimetres could put hundreds of millions of people at risk of losing their homes – or their lives – to flooding.

Still, the melt rates for many regions of Antarctica remain poorly studied, as thick sea ice can prevent research vessels from getting close enough to make the needed observations. That was the case for East Antarctica's Shirase Glacier until a huge ice-calving event in late 2016 finally opened a path to the glacier.

In early 2017, scientists aboard a Japanese research vessel sailed close enough to the Shirase Glacier Tongue to analyse 31 different points around the ice shelf, measuring the temperature, salinity and oxygen levels of the surrounding water.

The team revealed an 'atypical hotspot' of warm ocean water rushing along a previously unknown trough hundreds of metres below the Shirase Glacier Tongue. That warm water collides with the glacier's edge and ricochets upward, strafing against the bottom of the ice tongue before U-turning back towards the sea again, taking a load of melted ice with it.

While the fate of a single ice shelf isn't enough to drastically change the outlook for future sea-level rise, understanding how ocean currents interact with little-studied parts of the Antarctic ice sheet is a crucial part of predicting how quickly the continent could succumb to climate change.

HEALTH

Teen swallows a pin and pierces his heart

Words by Rachael Rettner

When a teen unknowingly swallowed a small sewing pin while tailoring his clothes, he didn't even notice. So it was a surprise to everyone when some days later doctors found it in a very unusual place: his heart.

The 17-year-old went to the emergency room after experiencing chest pain for three days. He said the pain was sharp, radiated to his back and was worse when lying down or breathing deeply.

The results of an electrocardiogram (ECG) – a test of the heart's electrical activity – were abnormal, and doctors were concerned the patient had perimyocarditis, inflammation of the heart muscle and the surrounding membrane. Lab tests also showed the teen had increased levels of proteins in his blood that can indicate heart injury.

A CT scan of his chest showed there was a 'linear metallic foreign object' lodged in his heart. The object was about 3.5 centimetres long and was jutting out of the heart's right ventricle, the lower-right chamber of the heart that pumps blood to the lungs.

The patient initially told the doctors he hadn't ingested any foreign objects or experienced physical trauma to his chest. But in a later interview he revealed that he tailors his clothes and sometimes holds sewing pins in his mouth. Still, he said he wasn't aware of ingesting a sewing pin.

He underwent open-heart surgery to remove the object, which doctors found was indeed a sewing pin.

© Getty

In 2016 doctors in China reported a 48-year-old woman had had a stroke after a needle pierced her chest and became stuck in her heart

SPACE

Vintage NASA satellite falls to Earth

Words by Meghan Bartels

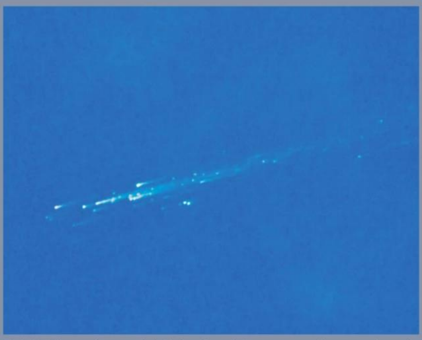
A long-retired NASA satellite burned up in Earth's atmosphere in late August. NASA launched the satellite, called Orbiting Geophysics Observatory 1, or OGO-1, in September 1964, the first in a series of six missions to help scientists understand the magnetic environment around Earth. OGO-1 was the first to launch but the last to fall out of orbit; the satellite had circled Earth aimlessly since its retirement in 1971.

Orbiting Earth is a tricky thing to do, since the particles in our plush atmosphere collide with spacecraft and slow them down – even at very high altitudes where the atmosphere is thin. That speed reduction also lowers the spacecraft's altitude more and more, until re-entry becomes inevitable.

The 487-kilogram OGO-1 experienced that inevitability on 29 August, as NASA had predicted. An updated re-entry prediction from NASA's Center for Near-Earth Objects at the Jet Propulsion Laboratory put the satellite's fall at about 20:44 GMT over the southern Pacific Ocean, with its burning up in the atmosphere posing no threat to humans.

The spacecraft hit the atmosphere about 25 minutes earlier than NASA had forecast, resulting in a re-entry location east of the agency's predictions. OGO-1 was forecast to re-enter about 160 kilometres southeast of Tahiti. In addition to tracking the satellite, NASA received reports of the event from people on the island.

OGO launches continued through 1969, when OGO-6 began orbiting Earth.



© B. Levionnois (Société d'Astronomie de Tahiti / l'Association Proscience) and P. Jenniskens (NASA / SETI Institute)

OGO-1 breaks up high in Earth's atmosphere when it re-entered on 29 August 2020

© Getty

Lystrosaurus was a dog-sized animal that thrived in the early Triassic Period and looked like a cross between a pig and a lizard

ANIMALS

Dr Seuss beast survived Triassic era by taking naps

Words by Yasemin Saplakoglu

Some 250 million years ago, a Seussian-looking beast with clawed digits, a turtle-like beak and two tusks may have survived Antarctica's chilly winters not by fruitlessly foraging for food, but by curling up into a sleep-like state, meaning it may be the oldest animal on record to hibernate.

Analysis of this Triassic vertebrate's ever-growing tusks revealed that it may have spent part of the year hibernating, a strategy that is still used by modern animals to tough out long winters. Like hibernators alive today, these ancient animals, who belong to the extinct genus Lystrosaurus, slowed down their metabolism and underwent periods of minimal activity when conditions got rough. "Animals that live at or near the poles have always had to cope with the more extreme environments present there," said Megan Whitney, a researcher in the department of organismic and evolutionary biology at Harvard University. "These preliminary findings indicate that entering into a hibernation-like state is not a relatively new type of adaptation – it's ancient."

Lystrosaurus – an ancient relative of modern mammals – could grow up to 2.4 metres long. The genus somehow managed to survive the planet's largest mass extinction, which happened at the end of the Permian Period about 252 million years ago and killed 70 per cent of land vertebrates.

"The genus survived the planet's largest mass extinction"

Researchers compared cross-sections of tusks from six Antarctic Lystrosaurus and four South African Lystrosaurus. The team found that the tusks from both regions had similar growth patterns made up of concentric circles of dentine, a hard, dense bony tissue. But the scientists also noted that the tusk fossils from Antarctica had some thick, closely spaced rings that the fossils from South Africa did not.

These thicker rings represent less dentine deposition and suggest that the animals went through periods of prolonged stress. "The closest analogue we can find to the 'stress marks' that we observed in Antarctic Lystrosaurus tusks are stress marks in teeth associated with hibernation in certain modern animals," said Whitney. However, it's not conclusive from the fossils if these animals truly went through hibernation, as the stress marks in their tusks could have been caused by a similar torpor, or period of decreased activity.

HEALTH

Africa declared free of wild poliovirus

Words by **Nicoletta Lanese**

Africa is free of wild poliovirus after decades of vaccination campaigns. An independent body called the Africa Regional Certification Commission (ARCC) for Polio Eradication made the announcement on 25 August during a World Health Organization (WHO) video conference. Of the 47 countries within the WHO's Africa region, Nigeria eradicated the virus most recently, and now four years have passed since the country's most recent wild polio case.

The disease known as polio is caused by three different strains of poliovirus, and sometimes attacks nerve cells in the spinal cord and causes partial or complete paralysis. The majority of people who become infected with polio don't become paralysed, but those who do can remain disabled for life or die from the condition, as the muscles that support breathing can be paralysed.

People can catch polioviruses through contact with the faeces of an infected person, or through contaminated food, water and objects that come in contact with the mouth. Less commonly, the virus can spread when an infected person sneezes or coughs. While there is no specific treatment for polio, a full course of polio vaccinations is more than 99 per cent effective at preventing the infection.

To snuff out wild poliovirus in Nigeria, a coalition of national governments and local leaders called the Global Polio Eradication Initiative coordinated a campaign to vaccinate children in Borno State, located in the northeast region of the country.

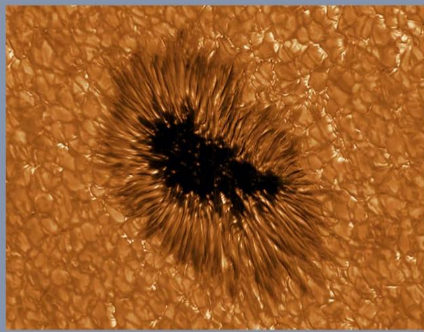
After years of vaccination campaigns, Africa has finally been declared free of wild poliovirus, but the work isn't over yet. Oral polio vaccines, including those used in Africa, contain a weakened poliovirus that can sometimes mutate into a form that behaves like the wild virus and can infect unvaccinated individuals. In areas with low vaccine coverage, outbreaks of vaccine-derived poliovirus can occur even when wild strains of the virus have been eliminated.

Nigeria and 15 other African countries are currently experiencing small outbreaks of vaccine-derived poliovirus, and in total 177 cases of vaccine-derived poliovirus have been reported in Africa this year. To avoid vaccine-derived polio, the US stopped administering oral polio vaccines in 2000 and now exclusively uses a so-called inactivated poliovirus vaccine, delivered as an injection and containing a dead poliovirus rather than a weakened one.

"The global eradication of polio requires stopping all [oral polio vaccines] in routine immunisation as soon as possible after the eradication of wild poliovirus transmission," the CDC website notes. With wild poliovirus eliminated in Africa, people must stay vigilant and keep up vaccination rates to avert a resurgence of the wild poliovirus and address the continued threat of vaccine-derived polio.

A schoolgirl is vaccinated against polio during a mass polio vaccination campaign on 12 April 2005 in Kano, Nigeria

For more of the latest stories, head to **livescience.com**



A high-resolution GREGOR image of a sunspot, a cool, dark magnetic storm on the Sun

SPACE

New images show our Sun's magnetic field structure

Words by Meghan Bartels

German scientists have upgraded a solar telescope called GREGOR at the Teide Observatory in Tenerife, and the result is a spectacular new set of images of our star. "This was a very exciting but also extremely challenging project," Lucia Kleint, a scientist at the Leibniz Institute for Solar Physics in Freiburg, Germany, said. "In only one year we completely redesigned the optics, mechanics and electronics to achieve the best possible image quality."

GREGOR began its observations in 2012 as Europe's largest solar telescope, and the upgrade project began in 2018. This included work on the telescope's optics and control systems, repainting the observatory to reflect less light and interfere less with observations and implementing new scheduling policies to improve the scientific output. The telescope now allows scientists to capture features on the Sun that are only 50 kilometres across. Since solar activity is currently on an upswing as the minimum point of the 11-year solar cycle ends, there will be plenty for GREGOR to study.

"Such upgrades usually take years, but the great teamwork and meticulous planning have led to this success," Svetlana Berdyugina, an astrophysicist at the Albert-Ludwig University of Freiburg in Germany and director of the Leibniz Institute for Solar Physics, said. "Now we have a powerful instrument to solve puzzles on the Sun."

WISH LIST

The latest **stargazing** gadgets

Meade Polaris 130mm reflector telescope

■ Price: **$199.95 (approx. £155)**
www.meade.com

Cast your eye towards the Moon's craters and Saturn's rings with this impressive reflector telescope by Meade Instruments. As part of the Polaris range, this telescope boasts a 130-millimetre aperture to provide a wide field of view and deliver detailed images. It also comes with a red dot viewfinder and three eyepieces to change the level of magnification. Each telescope in the series comes with AutoStar® software to help you learn about the night sky and discover more than 10,000 celestial objects such as galaxies, nebulae and planets.

© Hama

© Netatmo

Nikon D750

■ Price: **£1,199 / $1,699.95**
www.nikon.co.uk

If you're looking to capture the night sky, the Nikon D750 is one of the best DSLRs to do it with. Whether you're getting to grips with astrophotography or you're an experienced photographer, this camera is an excellent addition to your tool kit. Boasting full-frame 24.3-megapixel image capture, Nikon has produced a camera that can image the stars in extremely high definition. Due to the large image sensor, the D750 can receive light from faint objects and still produce stunning images.

© Nikon

Netatmo Weather Station

■ Price: **£299.97 / $369.97**
www.netatmo.com

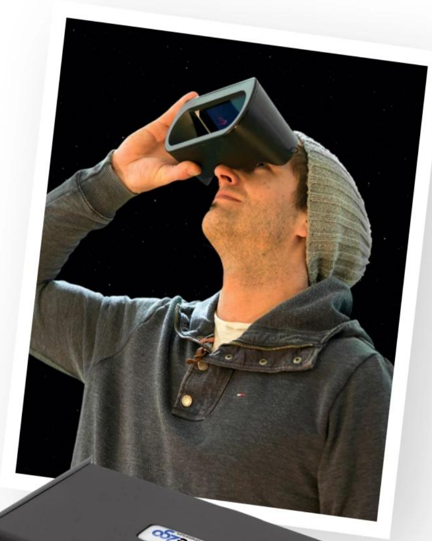
The weather can play an integral role in whether or not you're able to see the stars at night. The Netatmo Weather Station provides you with real-time data of your external environment, straight to your smartphone. By using outdoor sensors, this gadget can help you predict when is best to grab your telescope and head outside. The Netatmo Weather Station can calculate and forecast rainfall, temperature and atmospheric pressure, and provide you with a detailed graph of the week ahead. It also boasts the ability to monitor your indoor environment, measuring humidity, air quality and carbon-dioxide venting.

MasterClass Pro ED 10x42

■ Price: **$429 (approx. £332.20)**
www.meade.com

Combining the stargazing ability of a telescope and the durability of all-weather binoculars, the MasterClass ProMaster series by Meade Instruments is a quick-fire way to glimpse the night sky. Weighing less than 100 grams, these lightweight binoculars offer 10x magnification, and thanks to a lens coating can colour-correct your view to provide accurate sights.

© Meade



© Universe2go

StarSense Explorer LT 70AZ app-enabled refractor telescope

■ Price: **£135 (approx. $175)**
www.celestron.com

If you're a beginner to the world of stargazing, then this telescope is the perfect first purchase. Using its StarSense sky-recognition technology, simply mount your smartphone on the telescope and use the StarSense Explorer app to track star patterns and calculate their positions in real-time. The app will list possible sights for your location and help you direct the telescope to get the best views. It's also compatible with both Android and iOS smartphones, though models may vary. Using the eyepiece, this 80-millimetre refractor telescope guides you with an on-screen arrow until you've hit the target.

© Celestron

Universe2go

■ Price: **£44.90 / $49.90**
www.universe2go.com

Get closer to the stars with this augmented-reality viewer. Using your smartphone and the accompanying app, you can look through the AR lens and discover the night sky's constellations outlined. The app is jam-packed with information about each constellation and other celestial bodies, and comes equipped with audio guides on the history of the stars. This is a great gadget for the whole family, as well as budding astronomers looking to expand their knowledge of the universe around us.

APPS & TOOLS

The Moon

■ Developer: **Black Swift**
■ Price: **Free / Google Play**

Keep up to date on the current and future phases of the Moon and track each lunar month with this excellent calendar app.

Clear Outside

■ Developer: **First Light Optics**
■ Price: **Free / Google Play / App Store**

This app allows you to monitor how visible the night sky will be before heading out to stargaze. It's also equipped with ISS fly-over data.

Stellarium

■ Developer: **Noctua Software**
■ Price: **Free / Google Play / App Store**

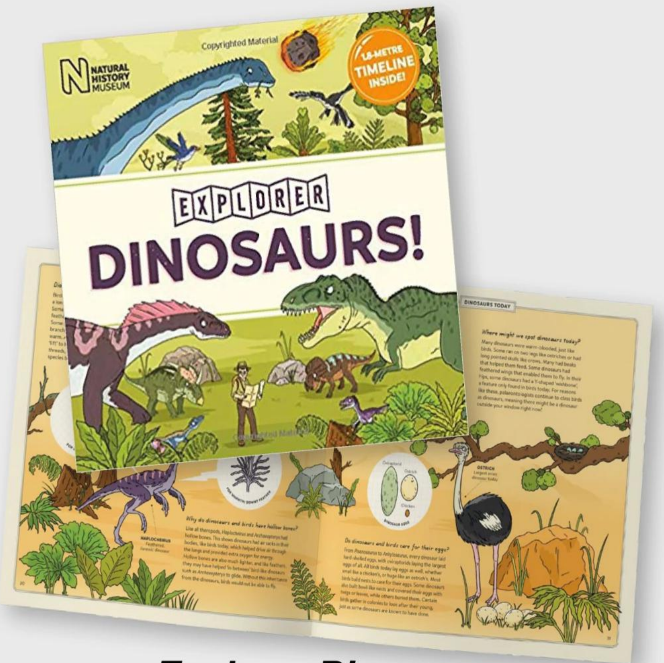
Get all the information you need about the different stars, constellations, planets and more in real-time, based on your location.

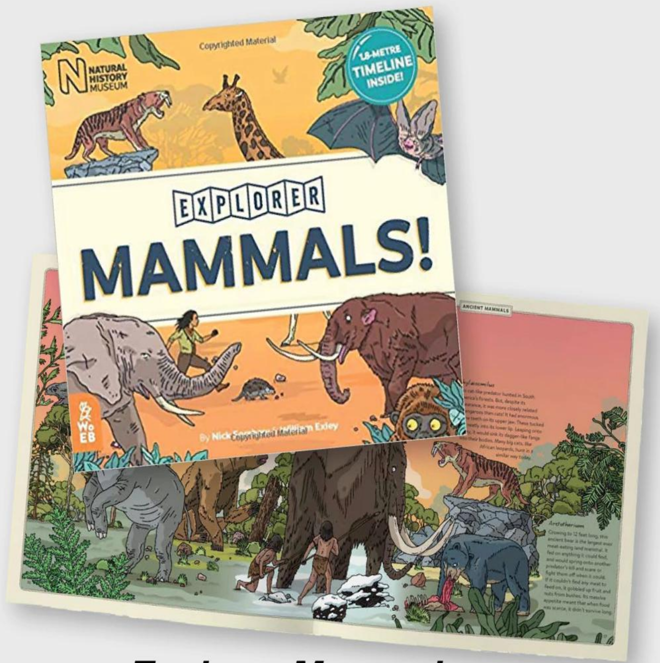
Meteor Shower Calendar

■ Developer: **Christopher Wilcox**
■ Price: **Free / Google Play / App Store**

You'll never miss a meteor shower again with this reminder app. With countdown and alert features, you'll be kept up to date on upcoming sightings.

SUBSCRIBE
TODAY AND RECEIVE
EXPLORER DINOSAURS AND EXPLORER MAMMALS BOOKS





Explorer Dinosaurs

Dig deep with our explorer to uncover the fascinating world of dinosaurs. A nearly two-metre-long timeline features over 100 dinosaurs from their first appearance about 230 million years ago through to their living descendants, the birds, today.

Explorer Mammals

Be on the lookout for the wildest mammals with Agent Osprey as she explores the animal kingdom in search of all things fierce and friendly! Includes a 1.8-metre-long timeline featuring over 100 mammals.

Though rarer, entire skeletons have been found perfectly preserved

© Shutterstock

Excavating is a slow process to avoid damaging the find

© Getty

DIGGING FOR DINOSAURS

Discover how a fossil hunter recently discovered a new ancient species. Could you make the next big find?

Words by **Ailsa Harvey**

How do you look for something that you aren't yet aware existed, from a world you can only try to imagine? It might seem impossible for us to study a species that we have never coexisted with, but this is something palaeontologists and fossil hunters do every day.

When humans first encountered dinosaurs, they had been extinct for over 65 million years. Everything we have come to know about dinosaurs today has been learned through our understanding of the planet's geology and analysing the ancient remains of these creatures. For this to happen, dinosaurs needed to have a lasting impact on the world, enduring tens of millions of years held inside solid rock. Luckily the remains of many types of dinosaur were preserved in the ground until humans could uncover them – and their secrets.

Fossils are impressions of ancient life, contained in the Earth's crust as a memento of life before the present. To palaeontologists they are hidden treasures, each with valuable information to share about a past geological and environmental age. The secret to their lasting form comes from the way they died. To become a fossil a dinosaur needed to take its last breath near water, or to have been buried alive.

Most dinosaurs wouldn't have died this way, so their remains would have deteriorated and can never be discovered. However, even for those that perished in one of these two ways, their bodies had to be surrounded by certain essential minerals to convert them into rock. Fossils are formed deep underground, where oxygen levels are so scarce that no bacteria can survive there. This means the body is unable to decay and lose its shape.

It's odd to think that these bones could be frozen in time only to be neatly retrieved from the ground as an almost-undisturbed stone skeleton. In some cases, not only are scientists presented with a perfect anatomical specimen to study, but they get an insight into a day in the life of a dinosaur – albeit their last day. Those that were suddenly buried alive can be retrieved in the exact position they died in. These are extremely rare fossils, but can provide information about the way a species lived.

Around the world, new dinosaur species are constantly emerging from rock faces, sandy dunes and clay-rich soils. But why are they being found now? To retrieve a fossil from sediment, the dinosaur first needs to be within reach. Sometimes it simply means being in the right place at the right time. You need to be near the land where the fossil has been held for millions of years just after the forces of nature have removed its rocky casing. The fossil then needs

5 FOSSIL TYPES

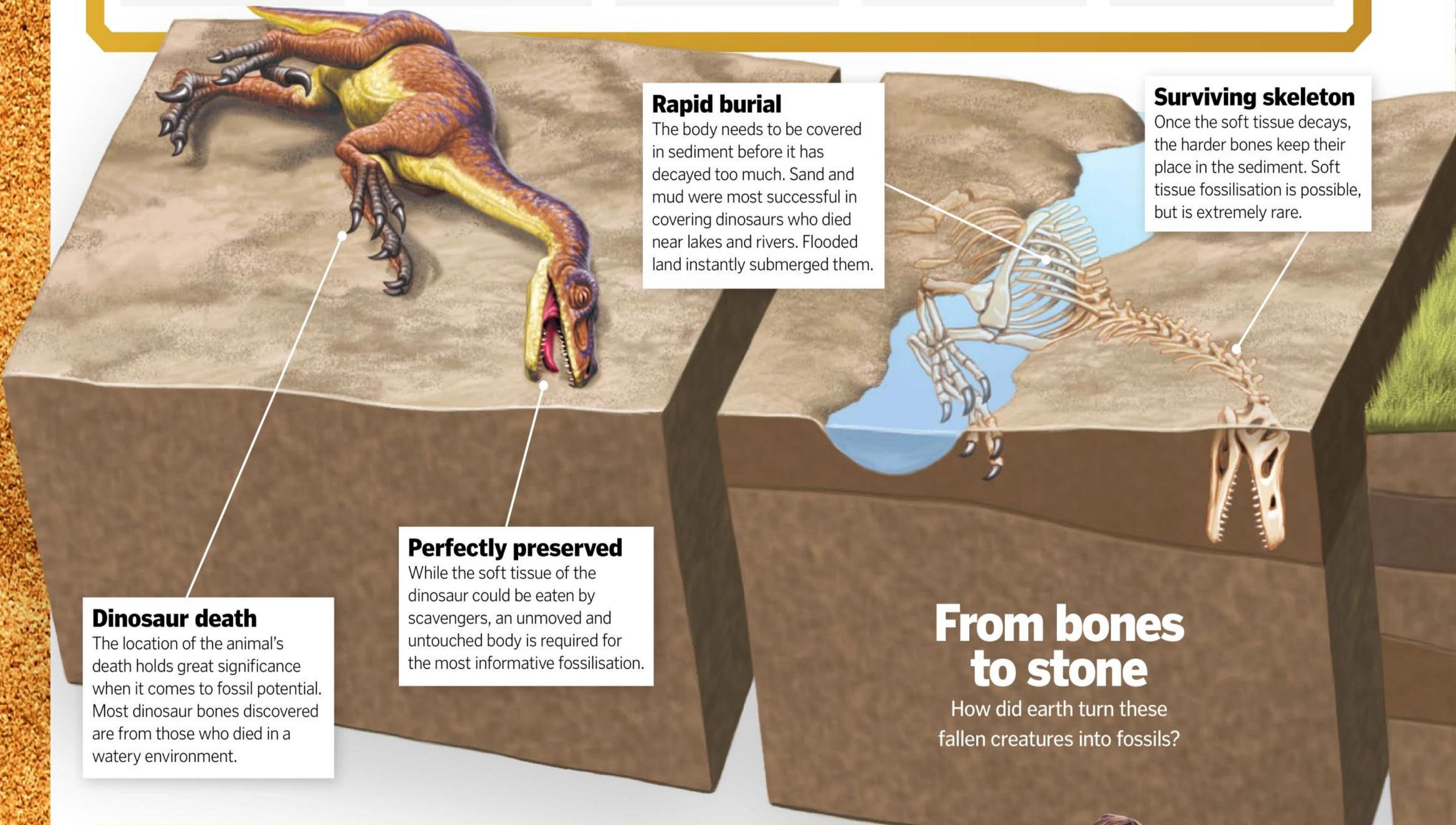
Mold
The rock of a mold fossil details the outside of the organism. After the sediment around it hardens, the buried plant or animal is dissolved by water, leaving an empty mold for a fossil.

True form
These fossils are created when the body of an organism is replaced with rock. It displays the organism's true form in great detail, rather than just being an impression.

Trace
Trace fossils aren't necessarily physical remains of an organism, but their formation displays traces of their existence. Examples include footprints, tooth marks and nests.

Carbonised
Created when a dead organism is buried on flat rock. Over time a thin carbon film is deposited onto the rock's surface. As the body decays, the carbon layer remains.

Cast
Cast fossils are more advanced mold fossils. Once the mold is created, the hollow area is filled with minerals, which harden to form a rocky version of the original organism.



Find your own fossil

Anyone can find a fossil, but to increase your chances you need to know what you're looking for. Many beaches are embellished with ancient marine life forms, but to seek out dinosaur bones you'll need more luck and patience alongside your knowledge.

First, you need to understand the rocks. By finding out how old the rocks are in the area you're searching, you can tune your hunt to the kinds of species you are likely to find. Next, pick your time. You can find fossils all year round, but from November to April is usually best. This is because rough seas and winter winds create movement on the beach, and this time of increased erosion can expose new fossils from the cliffs.

Always ensure you keep safe while searching for fossils. There's no need to climb cliffs, as many can be found loose on the ground. For your first search at least, you should join an expedition organised by experienced fossil hunters. This can provide you with information on what to look for and further useful tips to carry with you on your next hunt.

You can learn how to break rocks without damaging any fossils inside

to be retrieved before the conditions above the ground erode or damage it and render it unrecognisable. The reason that the number of finds has increased in recent years is in large part due to our expanding knowledge of the dinosaurs and the evolving technology that helps us to study them.

More people are out looking for dinosaur fossils today than ever before. We now know where the best places to look are, what kind of shapes the eye should be drawn to and the best times of year to search. Knowing where to look and what to look for has increased the success of beachcombing and geological digs.

"Sometimes it simply means being in the right place at the right time"

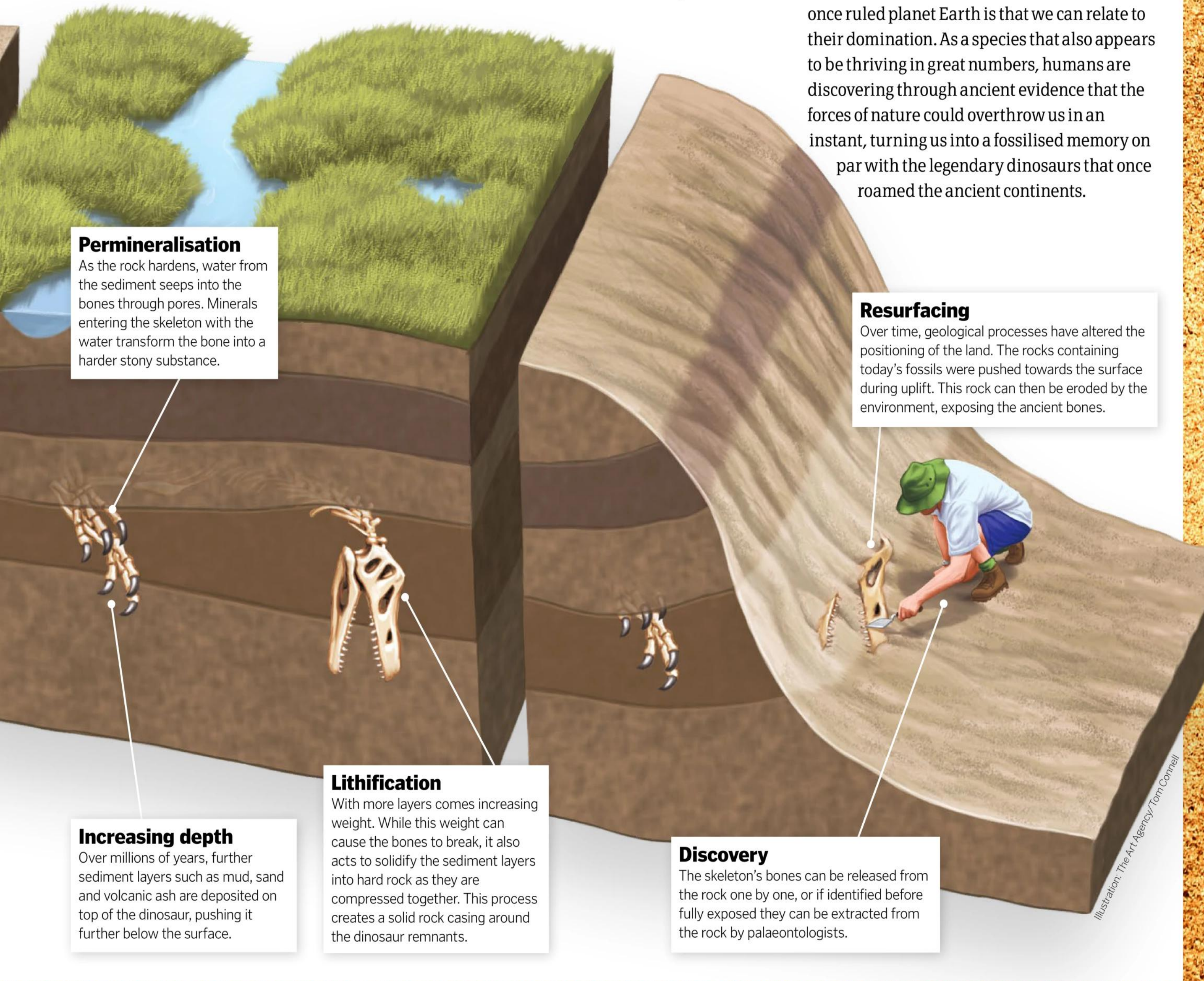
Although learning from previous finds enhances our understanding of what to look for next time, new species are often found in the least expected locations. One of the most recent dinosaur revelations was plucked from a British beach on the Isle of Wight last year, and after thorough research it was revealed to be a new species this summer.

This new species was retrieved from an unusual sediment type where the average fossil collector wouldn't think to search, showing that repeating methods of past finds doesn't always provide new results. This acts as an example that maybe the best way to search for something you don't know exists yet is not to search in conventional places at all. Sometimes the most notable fossils will find you.

The world of the dinosaurs seems so distant, but with every new species found we get closer to it. As our advancing knowledge of the relationship between each species grows, we have learned that dinosaur traits have been carried into the present day – and not just in their fossilised form. Modern birds actually originated in the Mesozoic Era, evolving from the theropod dinosaurs. Members of this group ranged drastically from the immense *Tyrannosaurus rex* to tiny bird-like creatures.

The sheer diversity between dinosaur species that have been discovered so far demonstrates just how much these animals evolved during their time on our planet. With every fossil that palaeontologists research, more pieces are added to the evolutionary story of the dinosaurs.

Perhaps one of the reasons humans have become so infatuated with these beasts that once ruled planet Earth is that we can relate to their domination. As a species that also appears to be thriving in great numbers, humans are discovering through ancient evidence that the forces of nature could overthrow us in an instant, turning us into a fossilised memory on par with the legendary dinosaurs that once roamed the ancient continents.



Permineralisation
As the rock hardens, water from the sediment seeps into the bones through pores. Minerals entering the skeleton with the water transform the bone into a harder stony substance.

Resurfacing
Over time, geological processes have altered the positioning of the land. The rocks containing today's fossils were pushed towards the surface during uplift. This rock can then be eroded by the environment, exposing the ancient bones.

Increasing depth
Over millions of years, further sediment layers such as mud, sand and volcanic ash are deposited on top of the dinosaur, pushing it further below the surface.

Lithification
With more layers comes increasing weight. While this weight can cause the bones to break, it also acts to solidify the sediment layers into hard rock as they are compressed together. This process creates a solid rock casing around the dinosaur remnants.

Discovery
The skeleton's bones can be released from the rock one by one, or if identified before fully exposed they can be extracted from the rock by palaeontologists.

Illustration: The Art Agency/ Tom Connell

A new dinosaur

Discover how a new species was uncovered

It was recently revealed that four dinosaur bones, found last year on the Isle of Wight, England, are those of an entirely new dinosaur species. Since October 2019 these bones have been held at the University of Southampton, where palaeontologists have been hard at work trying to discover what animal they belong to. They soon realised, after comparing each minute detail to a computer database, that this species had never been seen before.

Named the *Vectaerovenator inopinatus*, it is a member of the theropod family of dinosaurs, making it a close relative of the *Tyrannosaurus rex*. Its given name sums up many of its discovered qualities.

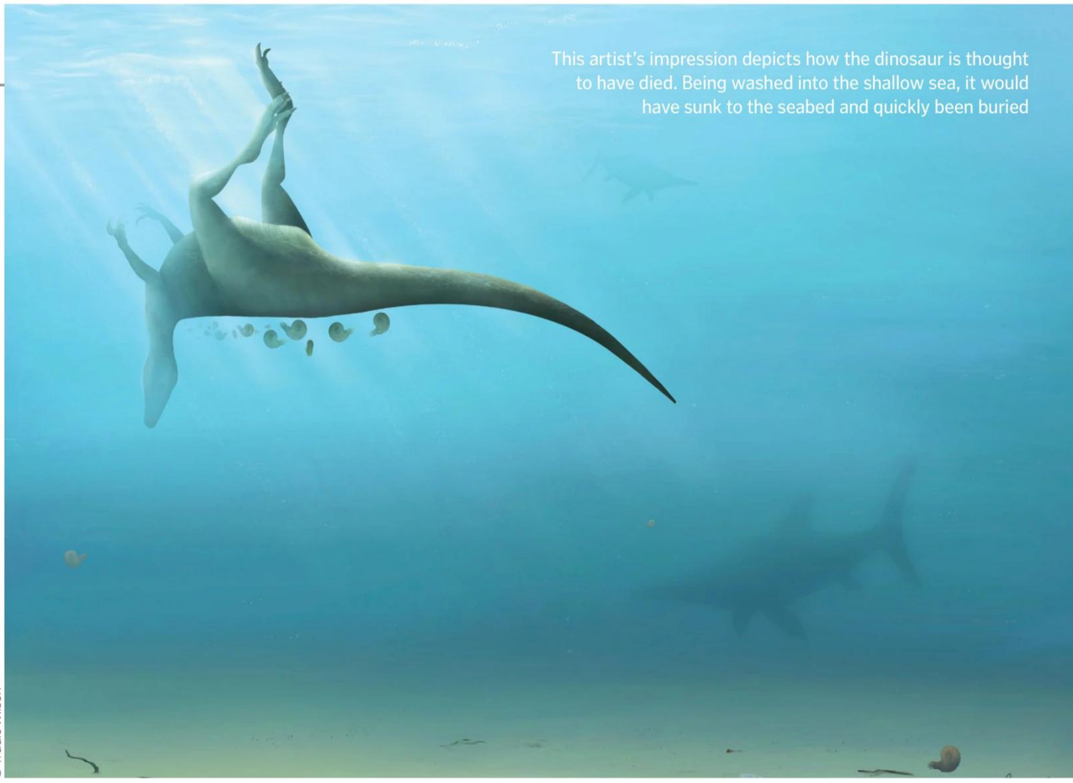
'Inopinatus' means unexpected. What made these bones particularly interesting to palaeontologists is that they were found in the lower greensand. This is a marine sediment which is a rare location for dinosaur fossils and a likely reason why the species had not been located before.

Neil Gostling, who supervised the study, said: "The Isle of Wight is the best place to find dinosaurs in Europe, but usually these finds are a terrestrial deposit. It is exciting because greensand is 116 million years old, and we have a poor understanding of European dinosaurs in this time period."

'Aero', which is incorporated into the new species' name, means air in Latin, and refers to the hollow properties of the four bones studied. They have large holes which would have been extensions of lung tissue for gas exchange.

"This is a very efficient way of getting oxygen into the body," Gostling said, "which some other theropods have as well. [The four fossils] don't feel like rock because they're almost hollow."

Despite only four bones being studied from this dinosaur, the university has already determined specific details about this ancient creature. Since the release of the findings another two bones from the same species have been handed in, and the researchers hope to soon reveal further information about it.

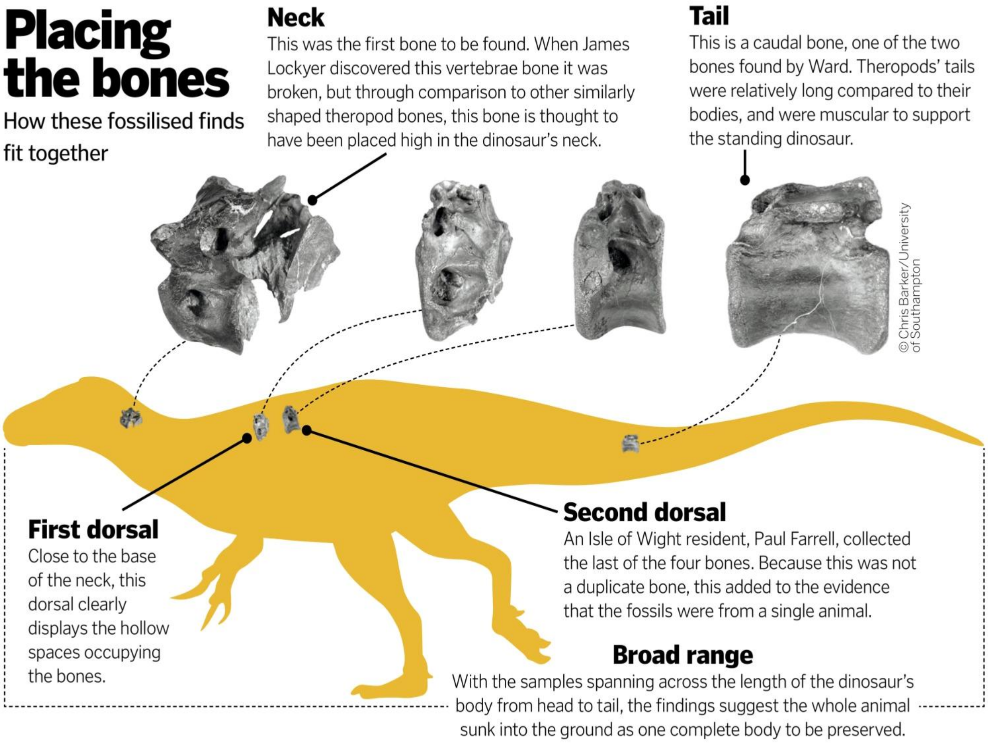


This artist's impression depicts how the dinosaur is thought to have died. Being washed into the shallow sea, it would have sunk to the seabed and quickly been buried

© Trudie Wilson

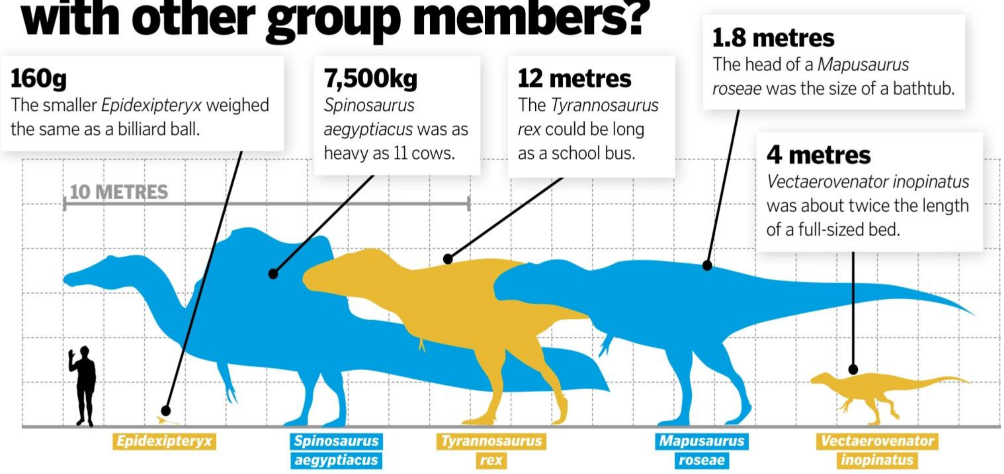
Placing the bones

How these fossilised finds fit together



© Chris Barker/University of Southampton

How does the new theropod compare with other group members?



Q&A

Fossil hunters who hit the jackpot

Ward discovered two of the dinosaur's bones

Lockyer found a bone from the neck

Robin Ward and James Lockyer weren't expecting to find a new dinosaur species when they visited the Isle of Wight last year. In March 2019 Lockyer discovered one of the dinosaur's bones, and Ward found two more in May. The fourth bone involved in the study of this species was collected by Paul Farrell.

What brought you to the Isle of Wight?

RW: I have been to the Isle of Wight a few times, but it was my daughter who chose to go there this time, as it was her tenth birthday. When we arrived we were too early to check into the hotel, so we decided to go fossil hunting on Shanklin Beach while we waited.

JL: I have been fossil hunting for the last 10 to 15 years and went to the Isle of Wight because it is an area with rapid erosion of the cliffs. Because of that, it's a good place to find fossils.

How did you come across the bones?

RW: As I searched the rocky area, I knew a find was possible because there had just been a high tide, which could uncover fossils from the sand. When I came across the first one on the floor, I videoed myself picking it up and posted it online. I knew it was from a dinosaur. I found the second just five minutes later, about eight feet [2.4 metres] away. I was so chuffed I did a bit of a jig on the beach. It's the find of a lifetime.

> "I was told I wouldn't find much on Shanklin Beach"

JL: I was told I wouldn't find much on Shanklin Beach, but I like to look in areas where others don't. I began searching the foreshore among the rocks and there it was – half a vertebrae – popping out the rocky substrate. I went to wash it in the sea and saw that it had a nice shape to it.

When were you made aware of the significance of your find?

RW: The first was clearly a dinosaur bone. The second one was a different shape, but looked like the same rock. They were so close I thought they had to be from the same dinosaur, and they were.

Two days later I went to the Dinosaur Isle museum to see what I had found. The palaeontologists' eyes lit up as soon as they saw them. They couldn't find anything like them in their exhibit. It was only after they had been properly researched that I found out it was a new species.

JL: I knew I had found a vertebrae as I have an interest in archaeology and I am quite good at spotting bones. I also knew it was a fossil.

At the museum, they were very interested in it but weren't sure what it was. They said it was the best find of the year so far. But it was when they got involved with the University of Southampton that things got more interesting and they established what it really was.

How does it feel to be linked to the discovery of this species?

RW: It's like winning the lottery. I fossil hunt all the time. Whenever I have five minutes I'll be looking through some gravel, but a dinosaur bone is the ultimate find. Gifting the bones to the museum was a bit like winning the lottery and then giving your money away, but if I hadn't they would only have had half of the bones they had to research, and I wouldn't know they were something special.

JL: It was nice to find it in the first place, but as time went on and I learned more about it, it got even more exciting. I think it's incredible that the university has the technology to identify something that we didn't even know existed. In a lifetime it is nice to have one notable find. To me all fossils are interesting to find, but to have my name against this find is exciting.

What do you like about fossil hunting?

RW: When you crack open a stone, most of the time there will be nothing in it, but when you do find something, you're the first person on Earth who's ever seen it. That's such a good feeling in itself.

JL: Ever since I was young I've liked searching. I was always digging holes in the garden. I didn't always know what I was collecting until I started fossil hunting more seriously and began learning about the geology of what I was finding. The best bit is not knowing what you're going to find. A lot of the time you don't find anything, so when you do there is a thrill.

How does this dinosaur compare to your previous finds?

RW: This was my best find in the fact that it is a new species. I have also got an ichthyosaur skull, which was a cool find. That was a reptile that swam in the sea a bit like a dolphin.

I've had many less successful searches. Once I found a shell which was probably 400 million years old. I threw it over to my son to have a look and he chucked it straight into the sea, thinking it was just a stone. No one will see that ever again.

JL: I've found marine reptile bones and various other fossil types. One of my personal favourites has been fossilised seeds. They are fascinating because they look like the seeds we have today but they are millions of years old. It's quite incredible to think that would have been the life of a new plant.

Five fantastic finds

Discovered fossils of some of the most mesmerising moments in prehistory

1 FOREVER FIGHTING

Mongolia 1971

When these dinosaurs began this fight around 80 million years ago, they probably didn't know they were fighting to the death… of them both. This fossil of a Velociraptor and a Protoceratops was discovered in a tangled scrap within the Gobi Desert's sandstone cliffs. The Velociraptor has its foot claw in the neck of the Proceratops, which is biting back at its opponent's arm. It is believed that a sudden sand flow buried them mid-fight, freezing the moment.

© Yuya Tamai

2 LARGEST *T. REX*

Canada 1991

The *Tyrannosaurus rex* is probably the world's most well-known dinosaur. Their towering stature contrasts comically with their dinky arms. After more than 20 years, research of Scotty brought this enormous species to a new level. At 13 metres long, his leg bones suggest that he would have carried a weight of 8,870 kilograms. This makes him the largest of his kind to be found.

© Kumiko

3 MOST PRESERVED DINOSAUR

Canada 2011

When miner Shawn Funk began digging in the Suncor Millennium Mine in Alberta, Canada, he wasn't expecting to unearth a 112-million-year-old armoured dinosaur. While this was impressive enough, this nodosaur had been preserved to keep the exact shape it flaunted while it roamed Earth. Because of its rapid sea burial, the dinosaur was below ground before it had time to begin decaying. The rock solidified around each scale, imprinting a detailed design on the petrified remains. The fossil provides scientists with extraordinary detail of the animal's skin, scale patterns and overall shape.

© ケラトプスユウタ

4 BIRD-LIKE BEHAVIOUR

Mongolia 1994

This small theropod, *Citipati osmolskae*, was fossilised while protecting its eggs between 83 and 66 million years ago. Spread out across its nest, just as birds often do, this find confirmed that nesting is an ancient behaviour. Uncovered from the sand of the Gobi Desert, the positioning of the body over the nest made it clear to palaeontologists that this species was guarding its young. This was the first substantial evidence showing this behaviour.

© Dinoguy2/Wikimedia Commons

© Getty

5 DINO EMBRYOS

China 2017

Finding dinosaur eggs is relatively rare, as many were soft-shelled and unlikely to become fossils. But in an even rarer case, palaeontologists in northwest China stumbled across over 200 dinosaur eggs. Within these eggs, 16 preserved embryos were found. The huge number of eggs are thought to be in the same area because the land was continuously flooded, but the dinosaurs used the same nesting site over a period of time.

© Natural History Museum of Utah/Michael Mozdy

Inside a palaeontologist's tool kit

What do you need to access hidden fossils?

1 Chisel
Dinosaur fossils are often found within rocks. Using a chisel and a hammer, rocks can be chipped away to reveal the inside.

2 Walkie-talkie
Some of the best finds are in extremely remote locations. If a group of fossil hunters splits up, contact with a designated base camp can be essential.

3 GPS
Keeping a record of where you are while looking for dinosaurs adds an element of safety. It is also ideal for documenting the exact location of the find.

4 Pointed-tip rock hammer
This tool is designed for use on hard rock. The flat end is used to crack open the rock and see inside without damaging any potential fossils within. The pointed end is used to dig a sample of the rock to analyse its mineral components.

5 Small probes and chisels
Accessing fossils can be a delicate procedure, requiring these small utensils. Fine-pointed picks work to uncover small fossils.

6 Dust brush
If fossils are covered in rock debris and dirt, soft brushes are a perfect way to reveal them without causing damage.

7 Swiss army knife
Compact and containing an assortment of small tools for every job, swiss army knives can be used to manipulate the rock on small samples.

8 Vinac
This solution of polyvinyl acetate adds a preservative coating to fossil finds. To stabilise dinosaur bones and stop them from breaking, they can be coated in vinac. The thin solution can be easily removed in a fossil laboratory later on.

9 Pens and bags
Fossils aren't always uncovered in one piece, with many found fragment by fragment. Plastic bags can hold pieces of a fossil together while you can use a pen to document how and where they were found, for future reference.

10 Measuring tape
Recording plenty of information about a fossil and its finding place is useful when it comes to researching the find. Measuring the distance between two found fossils can be useful in determining the likelihood that the bones are from the same animal.

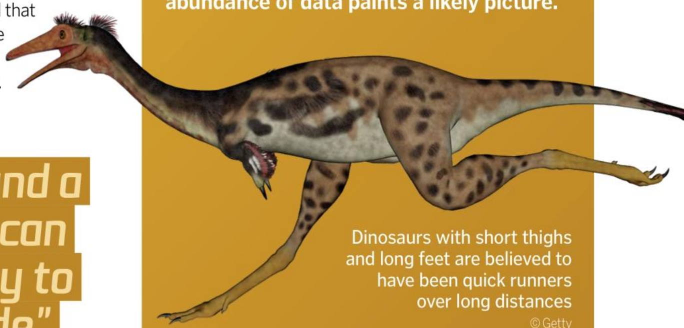
> "Using a chisel and a hammer, rocks can be chipped away to reveal the inside"

Extinct behaviour

Fossils can provide incredible details about dinosaurs' anatomy and what they looked like, but what can they teach us about their lifestyles? These limited remains don't tell us everything, often leaving scientists guessing about the colour of their scales and the sound of their roars. But when it comes to their behaviour, palaeontologists can analyse data from the fossils' locations and shapes of their features to link them to possible behaviours.

The size and shape of a dinosaur's teeth would have adapted to suit their diet, with long, sharp teeth indicating an animal that feasted on the meat of other animals. In some of the rarest fossils the contents of the stomach have been preserved – an even clearer answer to what was eaten.

When there is a combination of features all suiting a particular behaviour, this cements the hypothesis further towards certainty. Scientists can find clues in the structure of claws, fingers, wrists, joints and backbones that benefit a dinosaur's ability to dig. When all of these features are present, this abundance of data paints a likely picture.



Dinosaurs with short thighs and long feet are believed to have been quick runners over long distances

© Getty

How Venice was built

This much-loved Italian city was constructed on top of marshland

Despite Venice being frequently voted the world's most beautiful city, on paper it appears to be a logistical and constructional nightmare. It is largely built on marshland – a lagoon which is just eight per cent land – and one that contains some of the largest and heaviest religious and administrative buildings in Italy. And that's not even accounting for the dwellings of an estimated 60,000 residents and the risk – a very real risk as shown by history – of cataclysmic flooding. So how exactly does Venice, 'the floating city', keep above the water?

Key to its construction is an ancient method of using raised foundations, which effectively elevates ground zero to a height where buildings can be safeguarded from tidal waters. This involves the hammering of thousands of pilings – large wooden stakes commonly made from alder – through the water and into the underlying sand and clay. Each piling is positioned very closely to its neighbouring stake, placed one after the other, ultimately forming a raised wooden platform. Once a certain number of pilings have been driven into the earth, the tops are evened off and a substrate – or foundation layer – of wood and marble is laid over the top. It is upon this which Venice's buildings are constructed.

However, raising buildings out of the water is but one half of building in Venice – the other being to successfully channel the lagoon's waters into commutable highways. Venice's canals, which run for a total of 42 kilometres, are built and maintained in a multi-stage – and never-ending – process that begins with the construction of a cofferdam. A cofferdam is a temporary barricade that, once erected, allows a portion of the lagoon's waters to be blocked and redirected, which is necessary for any building work to take place. Once the damming structure is in place, the draining of the area can start, with industrial pumps removing any remaining water held in the channel. Next, large-scale dredging takes place, with huge diggers and cranes excavating the channel.

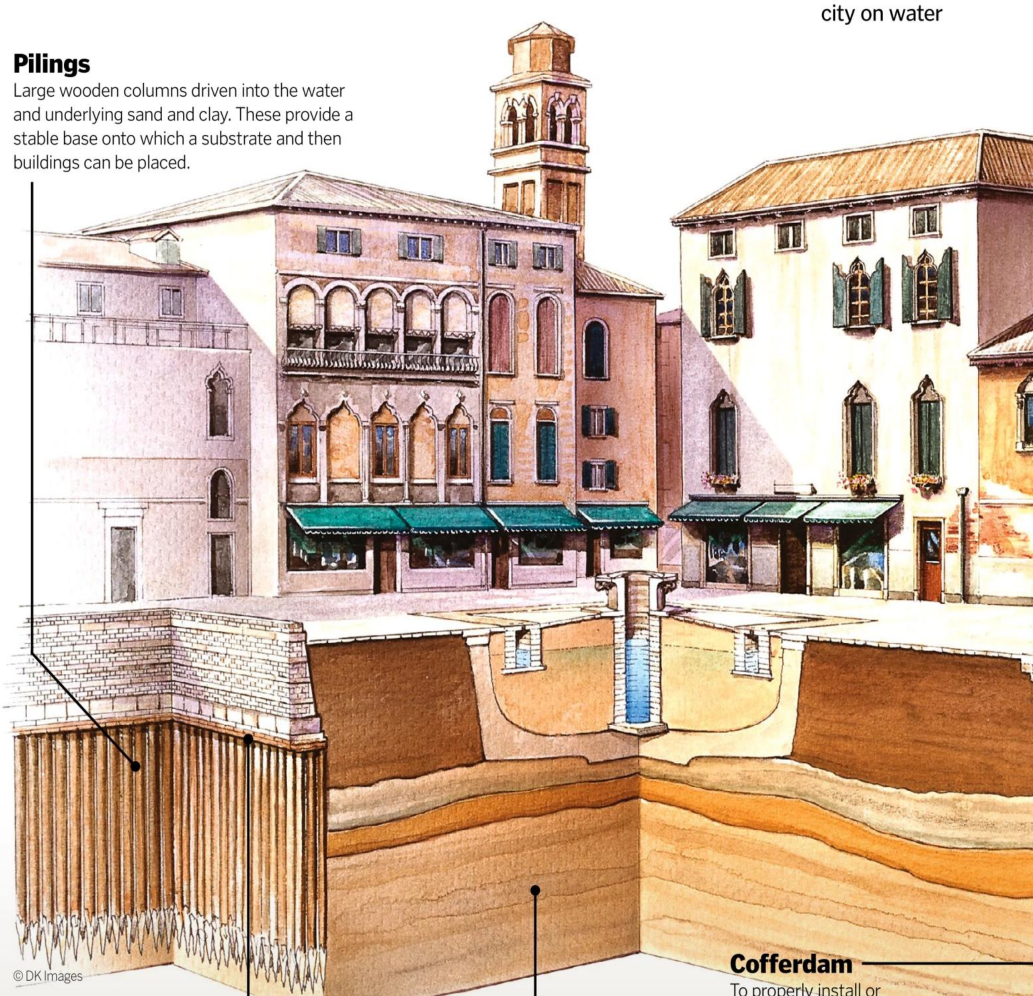
Once the channel is clear, engineers can begin fortification of the canal, utilising pilings, bricks, clay and – more frequently in recent years – cement to line and strengthen its core structure. Wooden pilings are still used today because when submerged the almost-zero-oxygen environment of the canal preserves them incredibly well, as well as bolstering their strength further through petrification – an effect caused by the flow of mineral-rich waters in their immediate vicinity.

Finally, Venice's construction is protected by a series of flood-prevention mechanisms. These range from the installation of conventional concrete dams around the city through to a project initiated in 2003 to set up huge inflatable pontoons at the mouth of the lagoon when high waters threaten.

© Jikael

The floating city explained

The materials, tools and techniques required to build and maintain a city on water



© DK Images

Pilings
Large wooden columns driven into the water and underlying sand and clay. These provide a stable base onto which a substrate and then buildings can be placed.

Foundations
Venice's buildings are not placed directly onto pilings, but rather a dual-layer substrate made firstly from planks of wood and then thick sheets of marble – the latter being water resistant.

Islands
Very few buildings are built solely on pilings alone, with the Venetian Lagoon containing 117 small islands that are linked by bridges.

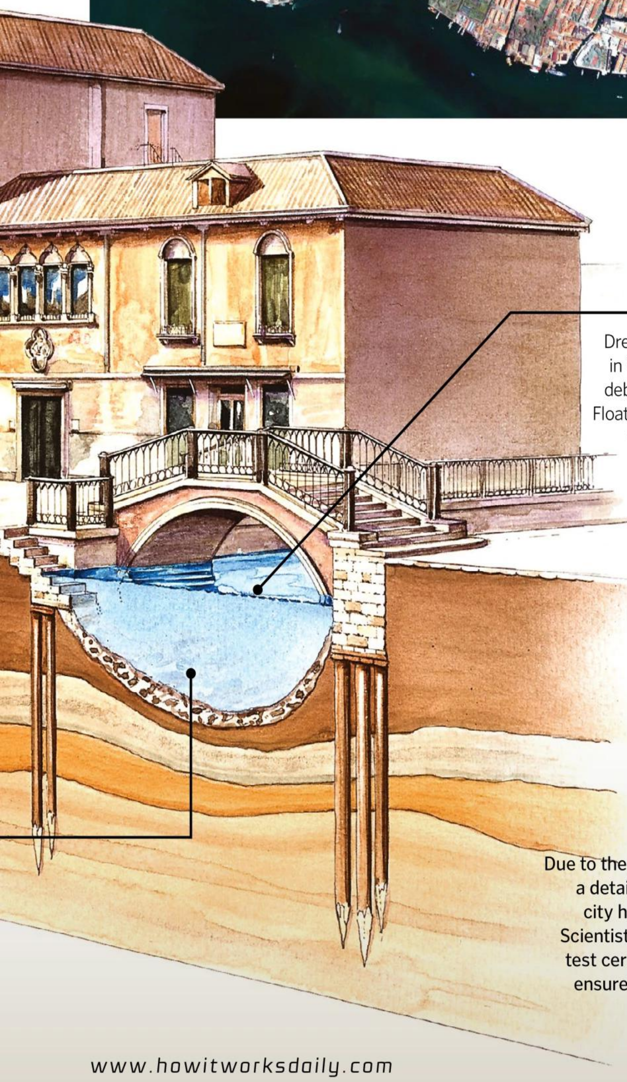
Cofferdam
To properly install or maintain existing pilings, as well as the canal walls themselves, engineers erect temporary dams called cofferdams in order to cut off and divert water flow.

A satellite view of Venice showing its complex network of canals

© ESA

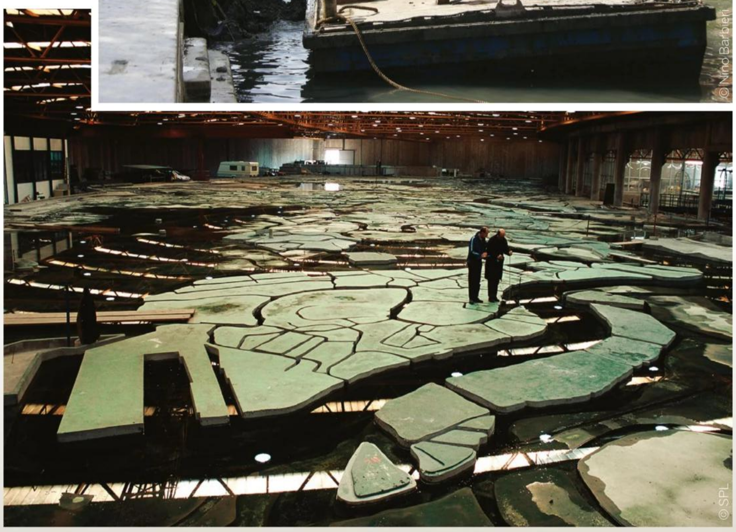
A floating excavator dredges debris from one of Venice's canals

© Nino Barbieri



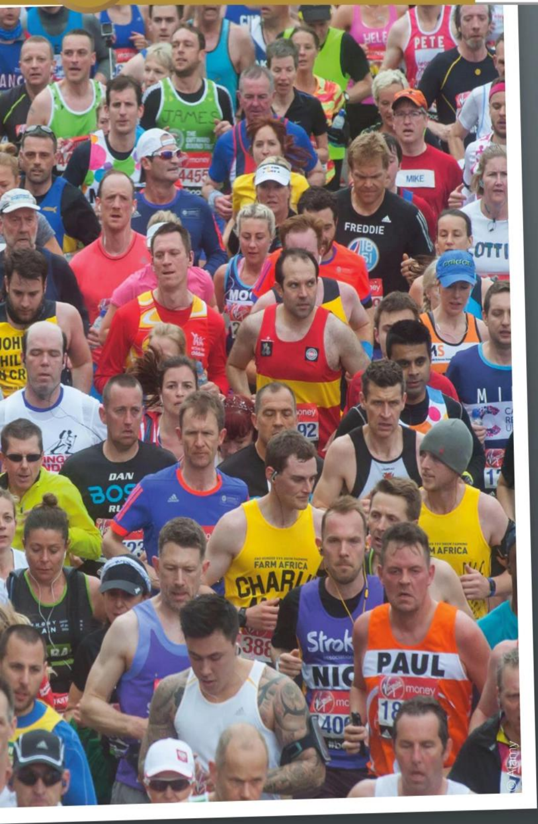
Dredging

Dredging is an ongoing activity in Venice due to the buildup of debris in and around its canals. Floating diggers are used to haul the flotsam and jetsam into mobile skips.



Due to the threat of floods, a detailed model of the city has been created. Scientists can use this to test certain scenarios to ensure better defences

© SPL



40 years of the London Marathon

Discover some of the marathon's best moments since it was founded in 1981

Words by **Ailsa Harvey**

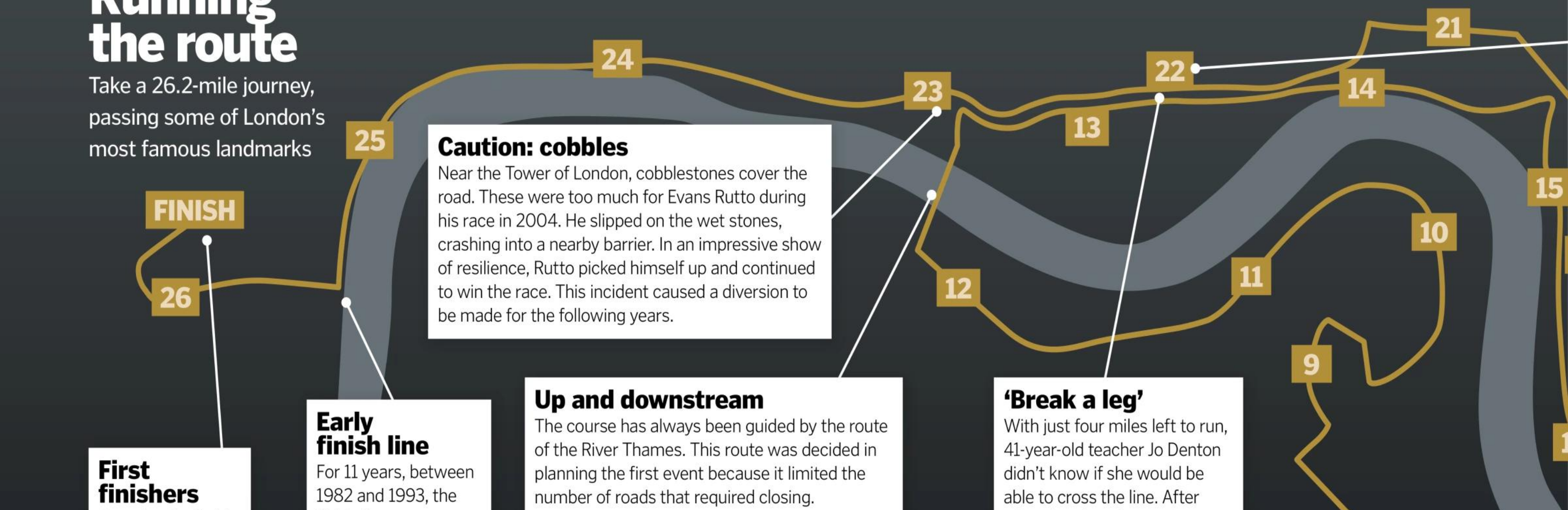
The London Marathon attracts a diverse group of athletes, from the world's greatest long-distance runners hoping to improve their personal bests to those whose ultimate dream is to be in the Guinness Book of Records for the most absurd outfits and feats. In the lead-up to the first few London Marathons, nobody knew the scale and success of what it would become.

The original organisers, Chris Brasher and John Disley, were intrigued to see if Britain's capital city was capable of hosting such a race as effectively as New York's marathon. 20,000 people responded with applications, giving the first indication of what it would become.

Since then the city's population has increased from 6 million to 9 million, and five times the 7,747 racers at the marathon's debut now take part in the annual event. This year has proven an exceptional one, with the pandemic cancelling mass participation in the 2020 marathon. But across nearly 40 years of annual events, there have been many standout episodes in its history.

Running the route

Take a 26.2-mile journey, passing some of London's most famous landmarks



Caution: cobbles

Near the Tower of London, cobblestones cover the road. These were too much for Evans Rutto during his race in 2004. He slipped on the wet stones, crashing into a nearby barrier. In an impressive show of resilience, Rutto picked himself up and continued to win the race. This incident caused a diversion to be made for the following years.

First finishers

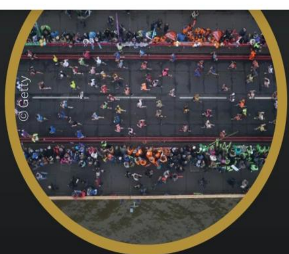
Crossing the finish line at the first-ever London Marathon were 6,255 people. Continuing to grow in popularity, this year's marathon would have seen over 40,000 people take part.

Early finish line

For 11 years, between 1982 and 1993, the finish line was positioned on Westminster Bridge with a view of the Houses of Parliament. After repair work on the bridge the finish line moved to The Mall, where it has been every year since.

Up and downstream

The course has always been guided by the route of the River Thames. This route was decided in planning the first event because it limited the number of roads that required closing.



Marathon runners cross the Thames on Tower Bridge

© Getty

'Break a leg'

With just four miles left to run, 41-year-old teacher Jo Denton didn't know if she would be able to cross the line. After what she thought was just a knee strain, she found herself in intense pain. Showing true sportsmanship, other runners carried her and pushed her in a wheelchair so that she could finish. Later she learned she had in fact broken her leg.

The first winners

At a time when photo finishes weren't in place, they became joint winners

At the London Marathon's debut on 29 March 1981, Norway's Inge Simonsen and Dick Beardsley of the US were among the thousands eagerly waiting at the starting line. The two men had challenged each other before and were keen rivals, so neither of them expected to finish in the manner they did.

As they ran close together throughout, it came down to the final leg when they both knew they had to make a break for it. When neither of them managed to drop the other, Beardsley suggested they cross the line together. In a spontaneous decision that led to what many believe to be the marathon's most iconic pictures, the two men crossed the line not only together, but hand-in-hand.

© Getty

London Marathon records

© Getty

Fastest course time 2019

Eliud Kipchoge currently holds the fastest marathon time in the world, and in 2019 earned the London Marathon course record with his time of 2:02:37.

© Getty

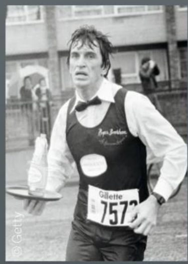
Oldest London Marathon runner 2004

Fauja Singh is believed to be the world's oldest marathon runner, running nine marathons since 2000. At age 93 he completed the London Marathon in 6:07, but his record since turning 90 is under six hours.

© Getty

Fastest marathon dribbling two basketballs 2015

Jerry Knox not only had to focus on his running, but controlling his basketball skills as he completed the marathon in 4:10:44. This world record was beaten last year in Poland.



© Getty

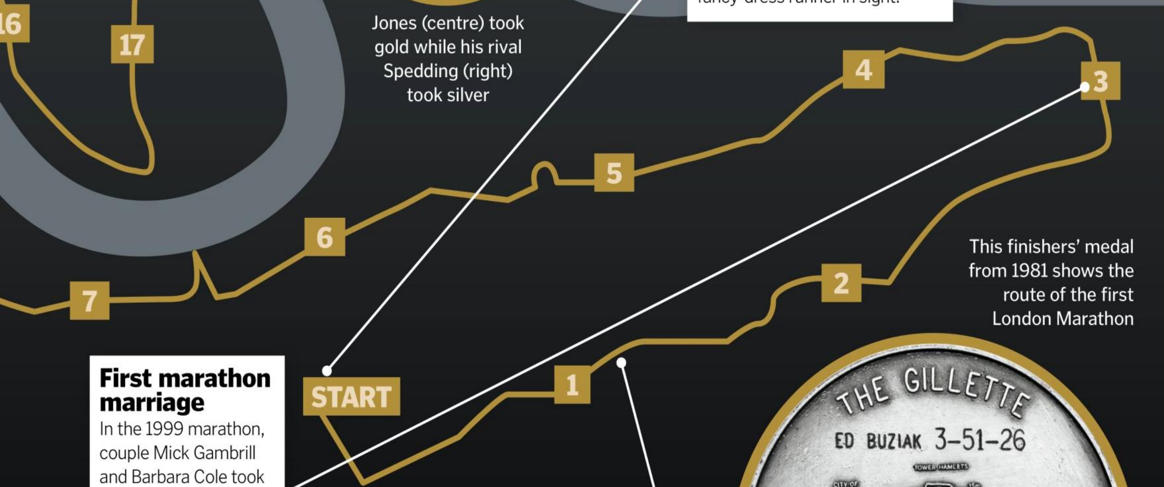
First costume worn 1982

In 1982 Roger Bourban completed the second London Marathon dressed as a waiter, believed to be its first fancy-dress runner. With his time of 2:47, he entered the Guinness Book of Records as the fastest waiter to run a marathon.

© Getty

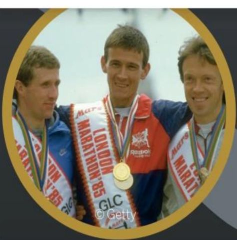
Fastest tent man 2019

Today the London Marathon is no stranger to unusual costumes. In the 2019 marathon, Oscar White crossed the line in 3:57:05, becoming the fastest man to run the distance dressed as a tent.

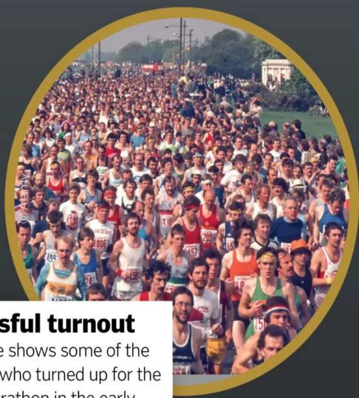


The famous pit stop

In the 1985 London Marathon, Steve Jones from Wales stopped after 22 miles due to a bad stomach. His rival, Charlie Spedding from England, gave him the advice to stop before running on. Luckily Jones didn't listen and – after a toilet stop – continued to overtake Spedding, taking the gold medal as well as a course record. His time of 2:08:16 remained for 12 years.



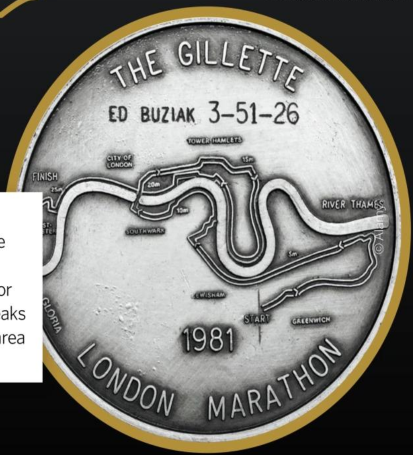
Jones (centre) took gold while his rival Spedding (right) took silver



Successful turnout

This picture shows some of the thousands who turned up for the London Marathon in the early 1980s exiting Greenwich Park. Unlike the most recent marathons, there isn't a fancy-dress runner in sight.

This finishers' medal from 1981 shows the route of the first London Marathon



First marathon marriage

In the 1999 marathon, couple Mick Gambrill and Barbara Cole took a break here in Greenwich to get married. Beginning the race as an engaged couple, they then continued post-wedding to cross the finish line as husband and wife.

Consistent course

The course has remained the same throughout the marathon's history, except for the finish line and minor tweaks such as avoiding a cobbled area near the Tower of London.

What to expect at the next marathon

The next London Marathon – if no longer restricted by coronavirus – is likely to have the largest turnout yet, with a range of races that will include elite, wheelchair and all abilities. If you're one of the thousands who plan on running, it is likely that you will have been preparing for months. Whether you feel fully ready to take on the streets of London or you don't know what you have let yourself in for, here are the top tips that have come from the millions of marathon runners before you.

The start is not the start

Due to the masses of people lining up at the start line, don't be alarmed when the starting gun goes and you don't move for a while. It could take 40 minutes just to reach the start.

Check the race map

While most of the time you are likely to be following those in front, know the route so you know where you are going. There should be water available every mile and toilets every two.

Don't buy new running shoes

New shoes might look good on the start line, but will only cause pain further down the line. Stick with the gear you are used to, limiting the likelihood of blisters.

Take headphones

For most of your run you will be encouraged by the sound of cheering crowds, but the course usually has its silent areas. A selection of upbeat songs can keep your energy and mood up as you get to more difficult sections.

Don't get too excited

You're finally at the event you've looked forward to and the lively atmosphere adds to the excitement. This adrenaline has caused many to use too much energy running fast in the first few miles. Make sure to maintain the pace you planned.

INVASION OF THE PESTS

How can farmers prevent insects from destroying our food supply?

Words by **Scott Dutfield**

In the natural world, insects play a vital role in creating and maintaining a global ecosystem, from the management of wild plant life to being an integral level in the ecological food chain. However, when it comes to agriculture their significant natural role quickly becomes a nuisance, and they are branded as a pest.

Insect pests are one of the biggest issues agriculture can face. Along with munching away at valuable crops, tearing leaves and devouring roots, they can bring with them bacterial, viral and fungal infections that wreak havoc on a crop's yield. To tackle the problem of pests, pesticides in the form of chemical, biological and even genetic measures are introduced.

Pest control has been around for as long as humans have been cultivating land, around 10,000 years, albeit in more spiritual and superstitious methods. By 2500 BCE some of the world's first civilisations used sulphur compounds to deter insect invaders. By 1200 BCE, in China chalk and wood ash were used to remove pests from stored grains. Treatments turned more chemically potent by 900 CE, when arsenic and cryolite were used as poisons and borax as an insect bait, luring them to death.

Over the years chemists and agricultural scientists have engineered and trialled a myriad of methods to keep pests at bay – with some more successful than others – including using other animals to do the farmers' dirty work and even genetically modifying crops to be better able to protect themselves.

Pests around the world

Aphids

© Getty

These sap-sucking insects are a common pest for farmers. There are more than 500 species in Britain, and they can eat plants during the day and night. Aphids excrete a sticky substance called honeydew, which can also produce a mould that can kill plants.

Fall armyworm

(Spodoptera frugiperda)

© Getty

Currently spread across sub-Saharan Africa and Asia, North and South America and Europe, this larval stage of the fall moth can devastate crops around the world. Consuming leaves and the reproductive parts of a plant, the armyworm can cause damage to more than 350 plant species.

Two-spotted spider mite

(Tetranychus urticae)

© Alamy

This spider-like mite can be found throughout the US, and gained its name due to the silk-like webbing the mites spin on host plants. Mite bites create grey or yellowing leaves, and if an infestation is big enough can cause complete defoliation of a plant.

Cotton bollworm

(Helicoverpa armigera)

© Getty

With a particular taste for cotton plants, through the six larval stages of a bollworm's life these pesky pests munch their way through the leaves and mine into the fruit of cotton plants – their seeds are destroyed, affecting future planting.

Red flour beetle

(Tribolium castaneum)

Source: Wiki/ USDA

In two to ten days these beetles can lay an impressive 450 eggs, making them a fast-growing pest problem. With a fondness for flour and grain stores, these beetles can cause flour to mould. They compromise grains with secretions from their scent glands.

© Getty

With the risk of developing cancer or neurological disorders when exposed to high levels of pesticides, farm workers are equipped with protective clothing

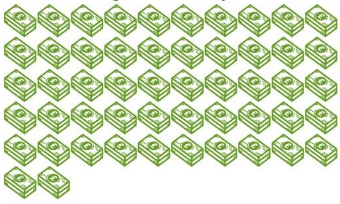
Source: Wiki/USDA

20 to 40%

Nearly half of crops worldwide can be lost annually to pests

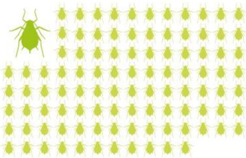
£52 billion

Pests take a considerable chunk out of the global economy



50 to 100

A single female aphid can produce an army of offspring



0.5 million tonnes

American farmers use a huge amount of pesticide every year

HOW INSECTICIDES REACH THEIR TARGETS

1 Direct contact
Chemical pesticides are directly sprayed onto the target pest, where the chemicals are absorbed by the insects.

2 Indirect contact
Similar to the direct contact method, the crop is sprayed with insecticide in anticipation of soft-bodied insects such as caterpillars walking over and absorbing it.

3 Ingestion
Insects such as beetles which munch on sprayed leaves will ingest the insecticide and die. With systemic insecticides a plant's sap will be ingested and have the same effect, since it contains the fatal chemical.

4 Fumigants
These gaseous airborne insecticides are released and settle on the soil to be absorbed. The intention is to control insects dwelling near the roots of the plant.

5 Pheromones
As a method to control insects reproducing and spreading, chemical pheromones are released throughout the crop. Pheromones are how some male and female insects find each other, so by introducing an artificial pheromone they become confused and can't find each other to mate.


© Getty

Chemical killers

The deadly chemicals that keep our food safe… or do they?

The most widespread method of keeping pests at bay is by chemical intervention. Created with the ultimate goal of killing the invading pests, there are many different branches of toxins used on crops. Currently more than 1,000 pesticides are used around the world to prevent food damage, each with varying properties and toxic effects.

The majority of insecticides are chemically engineered or naturally affect the nervous systems of an array of pest insects. Most of the pesticides used today affect the way insect neurons receive instructions to function by changing the sodium and potassium balance between the nerve cells. They either prevent a signal being generated or overstimulate the nerves so that they misfire. Either of these malfunctions of the nervous system will paralyse and then kill the pest.

Using chemical insecticides has been a controversial endeavour for some years, with their risk to human health being a major issue. In larger quantities pesticides can cause serious health issues, or even be fatal to someone that is exposed to them, which is why farmers must wear protective gear when spraying down their crops. However, pesticides in the past have caused larger scale problems in the surrounding ecosystem. Developed as the first modern synthetic pesticide in the 1940s, dichloro-diphenyl-trichloroethane (DDT) is now remembered as the biggest mistake in the history of agricultural pest control.

Created to combat pestborne diseases like malaria and typhus, the use of DDT quickly became its own health hazard. When exposed to high doses, it could cause vomiting, tremors and even seizures. Although highly effective as a pesticide, DDT was also very good at bioaccumulating, whereby an animal, such as a bird, eats the pest killed by DDT and accumulates it in their bodies, leading to a whole host of health issues. This includes making the shells of birds' eggs so thin that they break during incubation, destroying their population. As a result of the health hazards to both humans and wildlife, DDT was banned in the UK in 1984, but some countries still use it.

Today's harvested foods that have been treated with pesticides are rinsed and cleaned before they reach your plate. Regular pesticide residue testing is also done to ensure that any remaining pesticides are at a low and safe enough level for human consumption.

The bee debacle

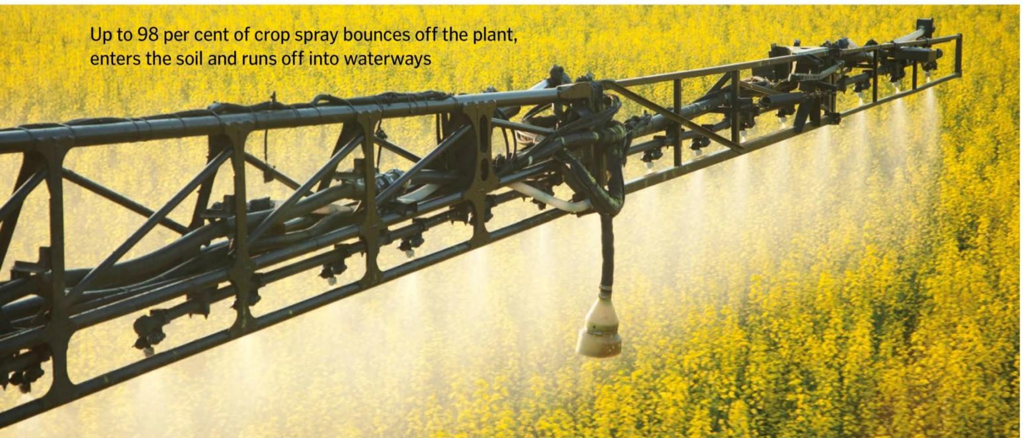
It's safe to say that bees are the backbone of our ecosystem, and are vital for successful harvests for some crops. As keen pollinators, honey bees are free labour for farmers, with over one-third of the food we eat depending on bee pollination. However, bees are being put at risk by a group of chemical insecticides called neonicotinoids. This synthetic chemical treatment is very effective at killing pests. However, it's not targeted towards unwanted insects, and so bees are also placed in the firing line.

Neonicotinoids work by compromising the insects' nervous systems and ultimately killing them. The chemicals also persist on the pollen of plants, thus finding their way onto a bee's body and resulting in their inevitable death. Studies have also shown that even a close proximity to neonicotinoids can disrupt a bee's ability to navigate and reproduce.

The use of neonicotinoids has been banned in part across all European Union member countries since 2013, and as of 2018 the ban extended to all outdoor use of the chemical. However, countries such as the US have not adopted the same ban on the controversial insecticide, but the Environmental Protection Agency persists to introduce measures to manage the risks they cause.


© Getty

Bees pictured in western France in 2018 to highlight the death of 20,000 beehive sites due to the use of neonicotinoids


© Getty

Up to 98 per cent of crop spray bounces off the plant, enters the soil and runs off into waterways

Drone farmers

It seems as though drones are flying into every avenue of business. From delivery drones to battlefield soldiers, drones are proving their worth as a versatile technology. So why aren't we seeing fleets of drones buzzing over farmers' fields and dishing out pesticides?

As autonomous machines, farmers could easily program the areas that need treatment and sit back and watch as the drones hover overhead and spray crops with manual assistance. However, in the UK, government regulations prohibit drones from aerial pesticide distribution. There have been trials in different areas of the UK, with the first crop-spraying drone taking flight in Norfolk last year.

With a ten-litre tank, the four-nozzle drone could control the rate of spray between six and 60 litres per hectare at a height of around 1.5 to 2.5 metres. Without the need to trample crops during manual spraying and their ability to reach difficult areas, trials like these offer insight into how these flying farmhands could be revolutionary for pest control.


© Getty

Drone use for pesticide dispersal is still currently illegal in the UK, but their future applications could revolutionise the way farmers protect their crops

Bring in the bugs

How using more insects could be the answer to chemicals

Tiny 'mummies' of aphids can be found with an exit hatch once wasps have emerged from within

Albeit an effective way to safeguard crops, chemical pesticides are not always the solution in the battle against bugs. Biological control agents, or BACs, as they are known, are predator insects or microbes that are used to remove pests by natural means. For example, aphids are a particularly destructive force for tomatoes and leafy vegetable crops, so to battle against the tiny green insects, hoards of their natural predator, the ladybird, can be introduced to remove them.

Another form of biological control is to introduce a group of insects called parasitoids. Rather than simply using the pests as a food source, parasitoids are a collection of insects that use crop pests as vehicles to gestate their young. By injecting larvae inside a pest host, young wasps then feed on the pests from the inside out, ultimately killing them and controlling the pest problem. It's unknown how many species of parasitoid wasps exist on Earth, with some estimates being placed up to 2 million.

Introducing a new insect species to outmatch another isn't always straightforward. Predators may cause unforeseen issues, such as broadening their meal choices and feasting on prey that isn't damaging crops. It's also been found that some BAC species end up not eating all the pests or even leaving the area of the pest problem before it's dealt with. As a more unpredictable solution to a pest problem, biological control isn't without its flaws, but offers a new way to tackle an old problem.

WHEN BIOLOGICAL PEST CONTROL GOES WRONG

1 Cane toad
In the 1930s, cane beetles wreaked havoc on sugarcane fields in Queensland, Australia. As a natural predator to the cane beetle, 102 cane toads were released in the hope they would remove the problem. However, the toads weren't interested in their new job as beetle killers, instead venturing away from the fields and beginning a new pest population, now more than 1.5 billion strong.

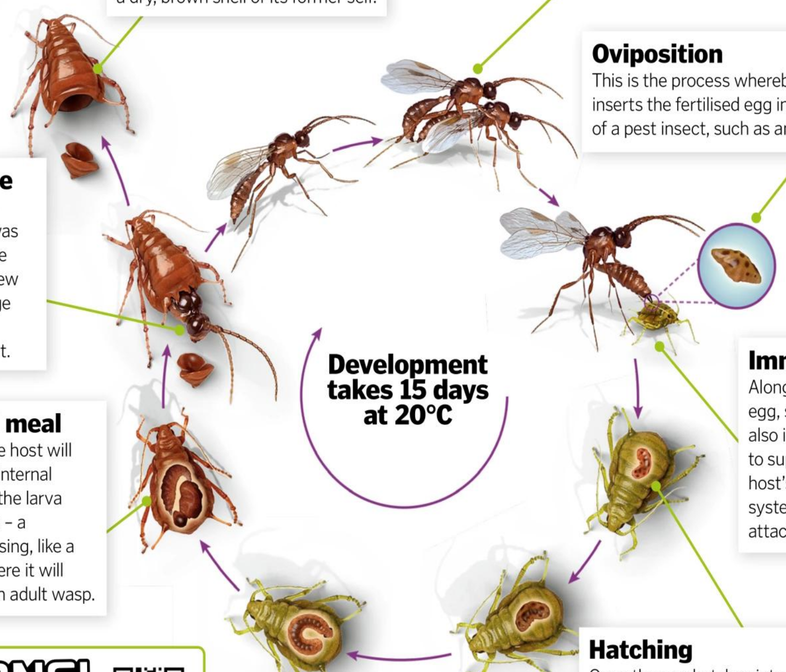
2 Cannibal snail
Back in 1955, the invasive African land snail was causing crop damage in Hawaii. A cannibalistic snail called the wolfsnail was brought in as a biological control. What was unaccounted for was a wolfsnail's indifference to which snails it ate, and currently Hawaii is battling to save native snail species from this voracious predator.

3 Harlequin ladybird
Introduced into Europe and North America from central Asia, this aggressive species of ladybird was introduced to eradicate pesky aphids. However, along with an appetite for aphids, they also brought parasites called microsporidia. These single-cell parasites are fatal to other ladybird species when they eat the harlequin's eggs.

4 Mosquitofish
As the name suggests, mosquitofish are known for their taste for mosquitoes. Introduced to Ohio in 1947, these small, grey fish are fierce predators, feasting on the underwater eggs and larvae of the annoying pests and keeping their numbers in check. However, they eat 42 to 167 per cent of their body weight a day, and so have turned on other native fish and invertebrates.

Eaten from the inside

How parasitoid wasps use aphids to grow their young



Fertilisation
Parasitoid wasps mate to produce fertilised eggs, housed in the female's body until she is ready to impregnate a pest.

Oviposition
This is the process whereby the wasp inserts the fertilised egg into the body of a pest insect, such as an aphid.

Immunity
Along with the egg, some species also inject a virus to suppress the host's immune system from attacking the egg.

Hatching
Once the egg hatches into a wasp larvae, it will feed on the blood and tissue inside the aphid to grow, avoiding vital organs to keep the host alive.

Finished meal
Eventually the host will die from the internal feeding, and the larva forms a pupa – a protective casing, like a cocoon – where it will morph into an adult wasp.

Emergence
Around 15 days after the host was injected with the wasp's egg, a new adult will emerge from the now-mummified host.

Mummified aphid
Having had the life literally sucked out of it, the host aphid appears as a dry, brown shell of its former self.

Genetic intervention

How altering a crop's genes can arm plants for insect warfare

Genetically modified (GM) plants have been produced since the early 1980s, with the first run of GM tomatoes hitting the shelves in 1994 in the US. In a nutshell, GM foods have been genetically modified by inserting a new chain of genetic information that plays a particular function from one organism to another. Scientists take the natural pest control abilities or disease resistance of one plant and put the part of the DNA that provides that ability into another plant.

Selecting desirable genetic traits in food products has been around for thousands of years. During the mid-1800s, Austrian scientist Gregor Mendel discovered that through selective breeding he could breed different generations of a plant to exhibit specific desirable traits, such as colour, ultimately opening the world's eyes to the existence of DNA. This technique could then be more accurately applied to crops to selectively breed plants to produce larger fruits, bigger yields and so on.

But there is a new technique emerging that could give plants the ability to repel pests without having to insert foreign genes. Known as Genome Editing induced Gene Silencing (GEiGS), UK-based biotechnology company Tropic Biosciences has created a novel approach to genetically altering crops to keep pests at bay.

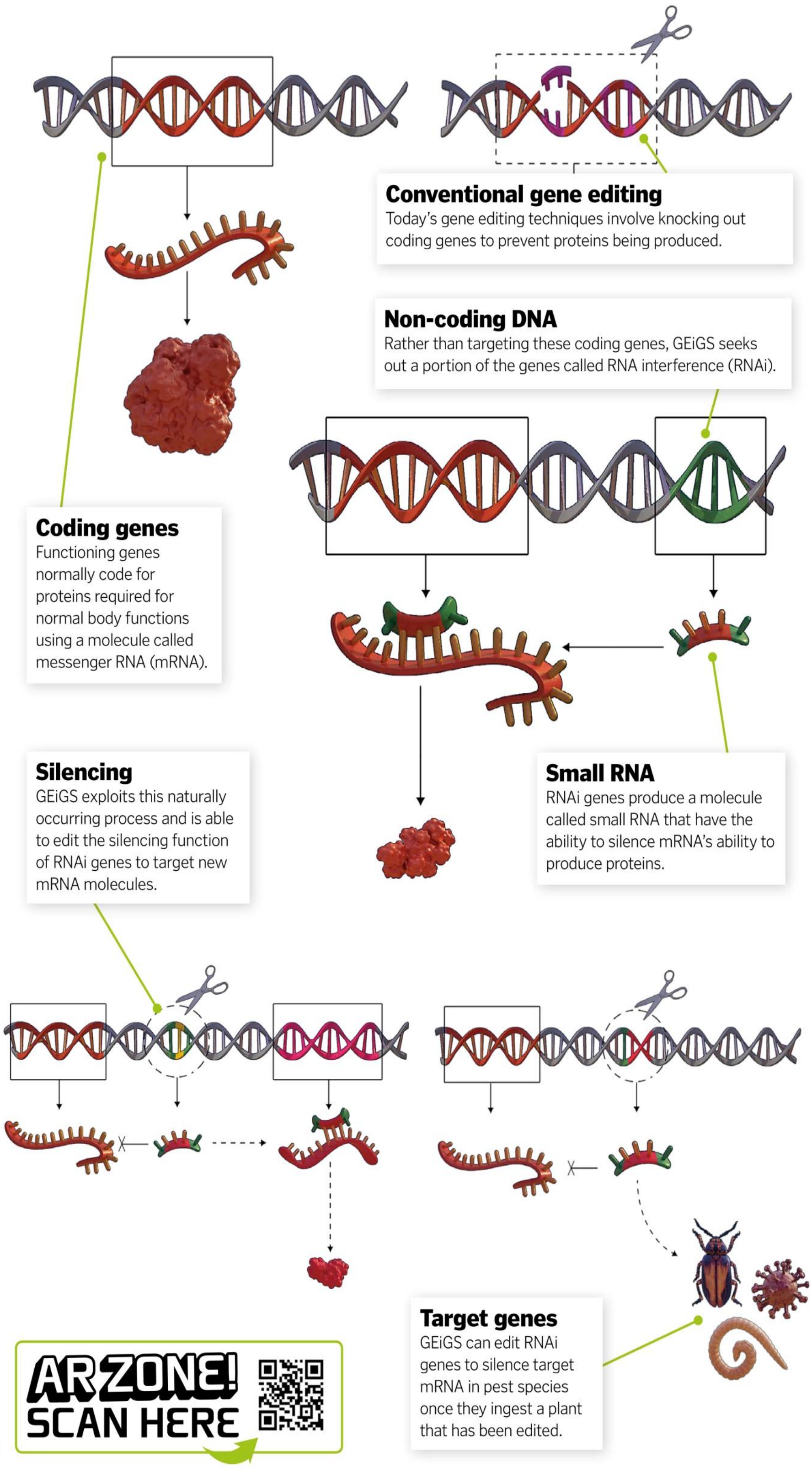
Rather than adding genetic information taken from another organism, GEiGS is a technology that can edit a sequence of genes that code for a molecule that can silence the function of other genes. Genes are like the blueprints of an organism's body, and their codes produce proteins that build and make the organism. If the production of these proteins is then turned off, that can cause the body to cease function and die. This is what GEiGS can exploit when dealing with invading pests.

Modified seeds might be able to fight off pests on their own

© Getty

DNA knockout

How GEiGS can change food genetics to embark on genetic warfare with invading pests



© Illustration by Nicholas Forder

Around 92 per cent of corn in the US is genetically engineered

© Getty

Pests and pesticides can both ruin a good crop

© Getty

Death by genetics

Tropic Biosciences chief science officer Dr Eyal Maori tells us how GEiGS is applied in the real world and how it could be used in the future

© Tropical Biosciences

How does GEiGS work?

The core principle of GEiGS is that we map all these RNAi genes, through minimalistic gene editing, changing maybe five to a max of 20 nucleotides. We redirect [them] to seek and destroy like smart missiles. Smart missiles have coordinates and explosive powers, so GEiGS is about changing the coordinates and keeping the explosiveness. We redirect the seek recognition of this molecule from one target to any target of choice. For example, we take an RNAi gene and we now target a nematode gene instead of other genes. Now you can redirect these RNAi genes against other genes within the plant cell to fight against a virus, fungus or any other pests.

How do RNAi molecules work against insect pests?

Ten years ago we thought that this seek-and-destroy mechanism works only inside cells. Before it was thought that this RNAi mechanism targets only intracellular parasites such as viruses. Then we learned that the RNAi molecules can move between cells. Then they can protect cells from a distance from the original cells that produce this RNAi molecule. Later on we found out these molecules can move not just between cells, but can move between organisms. So RNAi can be produced in one organism and can silence and target genes in a different organism. This is how it relates to the pest-control strategy. You can produce molecules in a plant that can recognise nematode – a parasitic worm – genes. The nematode is fed on the plant cells that produce the RNAi molecules. These RNAi molecules are taken up from the digestive system of the nematode and then they are spread all over the nematode's body and they are taken up by the nematode cells.

> "It's a genetic warfare, or arms race, between host and pathogen"

Within the nematode's cells these RNAi molecules know how to recognise nematode genes that are very important for the vitality of the nematodes. When they recognise these genes they target them, they destroy them and then the nematode dies.

So it's like a genetic poison?

In a way, but I wouldn't use the word poison. It's genetic warfare between host and parasite. What we have learned in the last three to four years is that plants produce natural small RNA that can target fungal agents. Apparently this transfer and communication of RNAi molecules have evolved as an immune mechanism of plants against a fungus. Also, it was discovered that fungus produces small RNA that is transferred to the plant to shut down the immune system of the plant. It's a genetic warfare, or arms race, between host and pathogen. It's this transfer of genetic information that is absolutely amazing; it's mind-blowing.

Does GEiGS affect the function of the plant species that's been edited?

Essentially not, because there are quite a few copies of the non-coding gene that we edit. We edit only some of them or even only one of them and we redirect its specificity and activity against, let's say, the nematode. The other copies still maintain a natural role. Essentially we just gained new protection and gained a function, while keeping the natural function intact.

What are the future applications of GEiGS?

GEiGS could be applied to diverse hosts – plants and animals, including aquaculture and livestock. Also, you could apply GEiGS to enhance the performance of crops or livestock. It's not just about protection, but also, for example, to increase yield and to promote resistance to droughts.

Hippo jaws

Why do these water-dwelling creatures open their mouths so wide?

A hippo may open its mouth wide as a sign of aggression, similar to other animals such as lions and baboons. Opening their jaws gives others a flash of their fearsome set of weaponry: their teeth.

Although hippos eat vegetation, they do not use their teeth to do so. Their giant canines and incisors are used only for killing. Instead they use their huge lips to rip grass from the ground for consumption. A hippo is able to spread its lips through a jaw-dropping 150 degrees and up to 1.2 metres in width. The strength of a hippo's jaw muscles – with a bite force of 1,825 psi – is such that it can use its fearsome teeth to bite a crocodile, human or even a small boat in half.

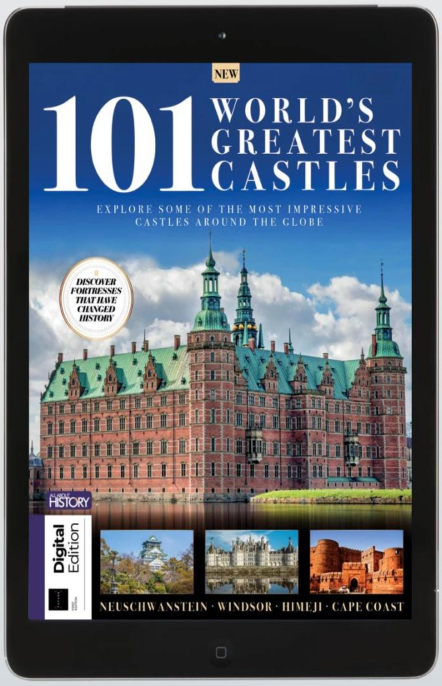
The skull of a hippopotamus contains tusk-like canines as long as your arm

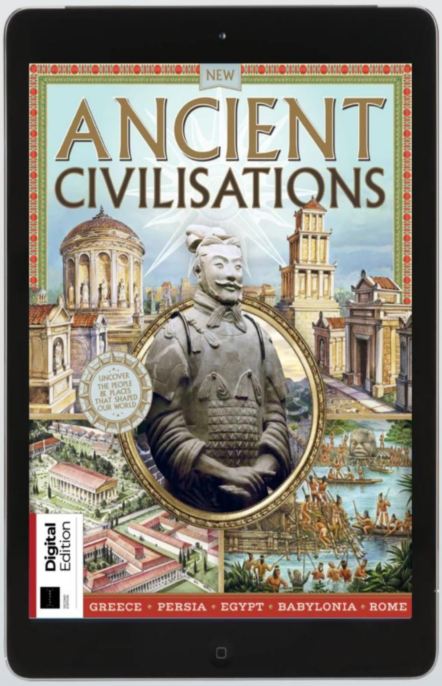
FREE

3 FREE eBOOKS FOR EVERY READER!

Grab yourself three fascinating, fact-packed **How It Works** specials for your digital device. Scan the QR code or type the link into your browser to download

500+ PAGES WORTH £30





World's Greatest Castles

Some were owned by counts, others the highest echelons of royalty. Some served as prisons with infamous inmates, while others were stately homes with beautiful banqueting halls and bedrooms. In **101 Greatest Castles**, it's time to uncover the most interesting castles from around the world. Go behind the fortifications to find out the true stories behind Dracula's home and the namesake of the House of Windsor. Meet the ghosts of haunted castles and walk the halls of some of history's most iconic buildings.

Ancient Civilisations

In **All About History Ancient Civilisations**, take a tour of antiquity as you uncover some of the greatest cultures the world has seen. Play a game of Pok-ta-Pok with the Mayans, wander the streets of Babylon and get up close to the Terracotta Army as we reveal some of the most interesting and exciting civilisations in Europe, Asia, Africa and the Americas. Turn the page, wind the clock back and uncover what life was really like for civilisations all across the ancient world.

World's Greatest Cities

The world is full of fascinating, diverse, exciting and cosmopolitan cities, each with their own extraordinary stories, culture, cuisine and history. In **101 World's Greatest Cities** we take you on a journey through the very best from each continent and bring you essential advice on planning your perfect city escape. Whether you're looking for enchanting architecture, stunning scenery, beautiful beaches, incredible history or something entirely different, there's something here for everyone.

Claim yours here: **bit.ly/2Fjrq2C**

THE POWER OF MAGNETISM

This invisible force allows the production of super-powerful electromagnets and everyday items such as credit cards, but what does it mean to be magnetised?

Magnetism is the force of nature responsible not only for our ability to live on a rock floating through space, but also for major technological achievements that have advanced the human race like never before. Our computers rely on them, our livelihood on Earth depends on their principles and our greatest science experiments use the most powerful magnets ever created by humans. Were it not for magnetism we simply wouldn't exist, and without discovering the power of this fundamental force of nature, our life on Earth would bear no resemblance to what it is today.

Scientists over the years have employed magnetism in new and innovative ways, delving into realms of particle physics otherwise unexplored, but let's first take a look at how basic magnets are made. It's fairly common knowledge that objects can be magnetised, making them stick to other magnetic objects, and we know that things such as a fridge or horseshoe magnet always have magnetism. To make permanent magnets like these, substances such as magnetite or neodymium are melted into an alloy and grounded into a powder. This powder can be moulded into any shape by compressing it with hundreds of pounds of pressure. A huge surge of electricity is then passed through it for a brief period of time to permanently magnetise it. Typically a permanent magnet will lose about one per cent of its magnetism every ten years unless it is subjected to a strong magnetic or electric force, or kept at a low temperature.

Now let's take a look at the magnets themselves, and what's in and around them. Surrounding every magnet is a magnetised area known as a magnetic field that will exert a force, be it positive or negative, on an object placed within its influence. Every magnet also has two poles: a north and south. Two of the same poles will repel, while opposite poles attract. Inside and outside a magnet there are closed loops known as magnetic field lines, which travel through and around the magnet from the north to south pole. The closer together the field lines of this magnetic field are, the stronger it will be.

This is why opposed poles attract – the magnetic forces are moving in the same direction, so the field lines leaving the south of one magnet have an easy route into the north of another, creating one larger magnet. Conversely, identical poles repel as the forces are moving in opposite directions, hitting one another and pushing away. It's the same effect as other forces. If you push a revolving door while someone pushes from the other side, the door stays still and your forces repel. If you push in the same direction, however, the door swings round and you end up back at your starting point.

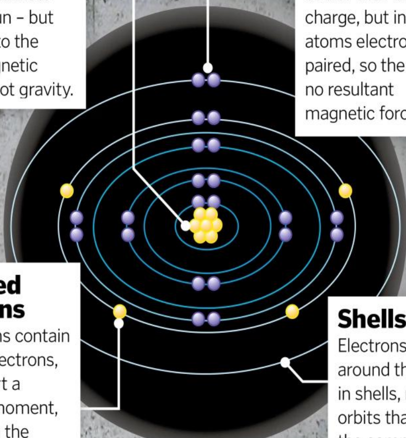
The defining feature of magnetic poles is that they always occur in pairs. Cut a bar magnet in half and a new north and south pole will instantly be created on each of the two new magnets. This is because each individual atom has its own north and south pole. However, the obvious question is why

Magnetic atom

What's the difference between the atoms of magnetic and non-magnetic elements? The main difference is the appearance of unpaired electrons. Atoms that have all their electrons in pairs can't be magnetised, as the magnetic fields cancel each other out. However, atoms that can be magnetised have several unpaired electrons. All electrons are essentially tiny magnets, so when they are unpaired they can exert their own force – known as a magnetic moment – on the atom. When they combine with electrons in the other atoms, the element as a whole gains a north and south pole and becomes magnetised.

Nucleus
Electrons of an atom orbit around the nucleus in the same way planets orbit the Sun – but this is due to the electromagnetic force and not gravity.

Paired electrons
Moving electrons create magnetism due to their electric charge, but in most atoms electrons are paired, so there's no resultant magnetic force.



Unpaired electrons
Some atoms contain unpaired electrons, free to exert a magnetic moment, or force, on the atom with a north and south pole.

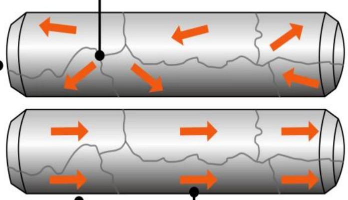
Shells
Electrons travel around the nucleus in shells, moving in orbits that result in the common description of them as rigid circles.

Inside a magnet

An object that can become magnetic is full of magnetic domains – chunks of about a quadrillion atoms. When the object is magnetised, the domains line up to and point in the direction of the magnetic field now present. This is why a magnetic object is sometimes stroked with a magnet to magnetise it. It aligns the domains in one direction so that a magnetic field is then able to flow around the material.

Unmagnetised
With no magnetism, the object does not have a north and south pole, so there is no magnetic field present to align the domains.

Scattered
When a substance that can be magnetic is unmagnetised its domains go in random directions, cancelling each other out.



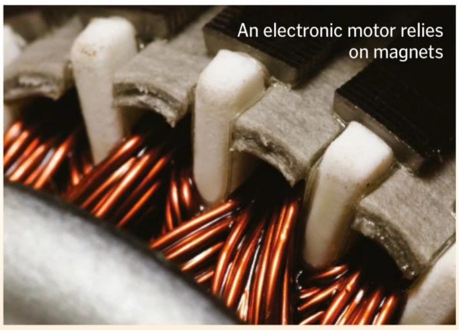
Magnetised
Introducing a magnet or electric current to the substance makes the domains all point in the same direction, with a magnetic field running from the north to south poles.

Aligned
When the domains are lined up the substance as a whole becomes a magnet, with one end of it acting as a north pole and the other a south.

the poles are there in the first place. Why do magnets have to have these field lines moving from north to south?

The answer involves magnetic domains. It is best to picture a magnet as smaller magnet chunks put together. Each chunk, or domain, has its own north and south pole, and again, as explained before, magnetic field lines travel from north to south. This means that all the domains stick together, with their forces concentrated in the same direction. They combine to make a larger magnet, exactly the same effect as when two magnets are stuck together. Each domain has approximately 1,000,000,000,000,000 – or 1 quadrillion – atoms, while 6,000 domains are approximately equivalent to the size of a pinhead. Domains within a magnet are always aligned, but elements such as iron that can become magnetic initially have their domains pointing in random directions when the iron is unmagnetised. They cancel each other out until a magnetic field or current is introduced, making them point in the same direction and magnetising the iron, which creates its own new magnetic field.

To really understand magnets, however, we need to get into exactly what is happening inside these domains. For that we need to get right down into the atom. Let's take an iron atom, for example. Electrons circle the nucleus of an atom in cloud-like orbitals, commonly described as



An electronic motor relies on magnets

Types of magnestism

Ferromagnetism

The strongest magnet in this list, a ferromagnet will retain its magnetism unless heated to a temperature known as the Curie point. Cooling it again will return its ferromagnetic properties. Every atom in a ferromagnetic material aligns when a magnetic field is applied. Horseshoe magnets are ferromagnets.

© Gregory F. Maxwell

Ferrimagnetism

Ferrimagnets have a constant amount of magnetisation regardless of any applied magnetic field. Natural magnets like lodestones, or magnetite, are ferrimagnets, containing iron and oxygen ions. Ferrimagnetism is caused by some of the atoms in a mineral aligning in parallel. It is different from ferromagnetism in that not every atom aligns.

© Ryan Somma

Antiferromagnetism

At low temperatures the atoms in an antiferromagnet align in antiparallel. Applying a magnetic field to an antiferromagnet such as chromium will not magnetise it, as the atoms remain opposed. Heating to Néel temperature – when paramagnetism can occur – will allow weak magnetism, but further heating will reverse this.

Paramagnetism

Paramagnets, such as magnesium and lithium, have a weak attraction to a magnetic field but don't retain any magnetism after. This is caused by at least one unpaired electron in the atoms of a material.

Diamagnetism

Gold, silver and many other elements in the periodic table are diamagnets. Their magnetic loops around the atoms oppose applied fields, so they repel magnets. All materials have some magnetism, but only those with a form of positive magnetism can cancel the negative effects caused by diamagnetism.

© Jeff Belmonte

rigid shells, although in actuality their motion is much more random. Each atom has a particular number of shells depending on how many protons and neutrons it has, while within each shell electrons orbit in pairs. Electrons are just like tiny magnets, each one having its own north and south pole. In their pairs, the electrons cancel out with one another so there is no overall magnetic force.

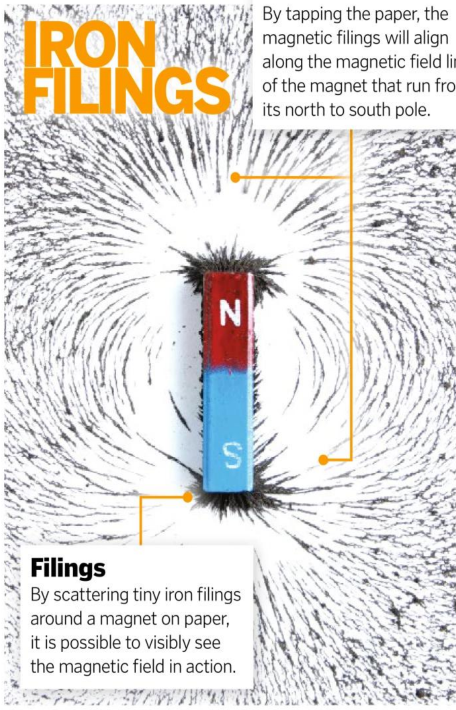
In an atom such as that of iron, however, this is not the case. There are four electrons that are unpaired, exerting a magnetic force on the atom. When all the atoms are combined together and aligned, as we explained when talking about domains, the iron itself becomes magnetised and attracts other magnetic objects.

We've snapped our magnet, broken it into chunks and subsequently examined the atoms of those tiny chunks. But can we go deeper? The answer to that is both yes and no as we delve into the unknown areas of quantum physics. The underlying principle of magnetism is that in the universe there are four fundamental forces of nature: these are gravity, electromagnetism, the weak nuclear force and the strong nuclear force.

Even smaller than atoms, protons, neutrons and electrons are fundamental particles known as quarks and leptons, which are responsible for these forces. Any force – such as gravity, magnetism, nuclear decay or friction – results from these four fundamental forces. A force such as magnetism at this level is 'thrown' between particles on what are known as force carrier particles, pushing or pulling the other particles around accordingly.

Unfortunately at this level magnetism goes into the realm of theoretical physics, entering areas of quantum physics that have not yet been explored in as much detail as particle physics. For now the Standard Model of physics explains magnetism to a level that can only be furthered when we advance our understanding of quantum physics in the future, which scientists today are striving for.

IRON FILINGS

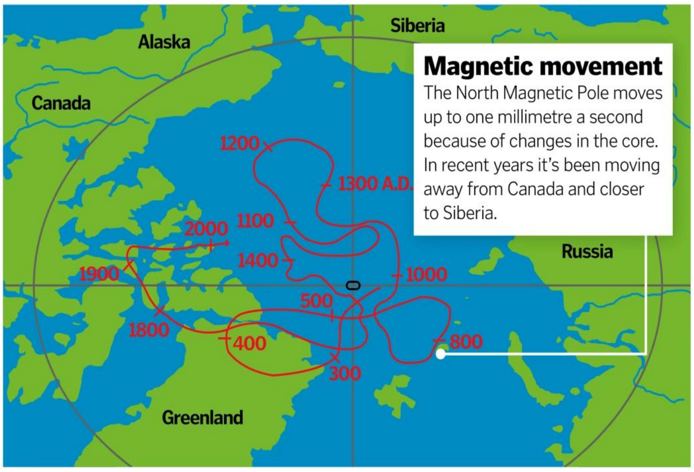


Field
By tapping the paper, the magnetic filings will align along the magnetic field lines of the magnet that run from its north to south pole.

Filings
By scattering tiny iron filings around a magnet on paper, it is possible to visibly see the magnetic field in action.

EARTH'S MAGNETIC FIELD

It's best to imagine Earth as a bar magnet 20,000 kilometres long. The magnetic fields move around us like they would in a fridge magnet, but they also protect us from the universe. Compass needles always point to a magnet's south pole, so the Earth's geographical north pole is actually magnetically south.

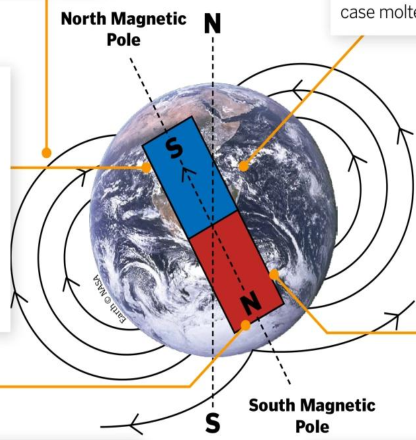


Magnetic movement
The North Magnetic Pole moves up to one millimetre a second because of changes in the core. In recent years it's been moving away from Canada and closer to Siberia.

Key: wandering path of the magnetic north
rotational north pole

Effect
Charged particles from the Sun are deflected by Earth's magnetic field, with some trapped in bands of radiation.

Cause
The magnetic field of any planet, including Earth, is the result of the circulation of electrically conducting material in the core – in our case molten iron.



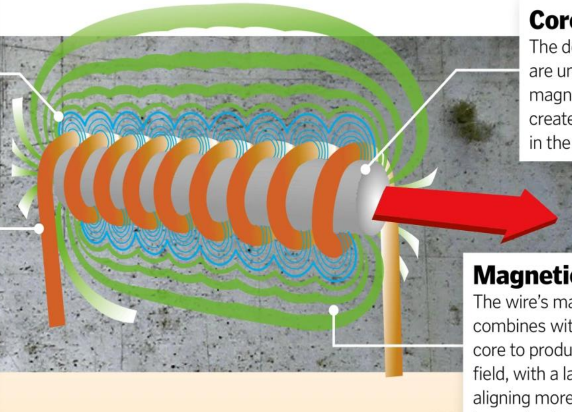
Tilt
The central 'bar magnet' of Earth's magnetic field, the dipole, is tilted approximately 11 degrees off Earth's axis.

South is north
Magnetic fields always run from north to south, so when a compass points to the North Pole it is actually indicating southern magnetic polarity.

Off-centred
The magnetic north and south poles do not draw a straight line through the centre of Earth. In fact, they miss by several hundred kilometres.

Electromagnets

One of the four fundamental forces in the universe, electromagnetism results from the interaction of electrically charged particles. Physicist Michael Faraday deduced that a changing magnetic field produces an electric field, while James Maxwell discovered that the reverse is also true: a changing electric field produces a magnetic field. This is the basis of how an electromagnet works.



Electric fields
A wire wrapped around a magnetic core, such as iron, produces electric fields when a current runs through it, in turn creating a magnetic field.

Coil
The number of coils will increase the strength of the electromagnet because there is more current flowing in one direction, magnifying the force proportionally.

Core
The domains within the core are unaligned until a magnetic field is introduced, created by a moving current in the coil.

Magnetic field
The wire's magnetic field combines with the field of the core to produce a stronger field, with a larger current aligning more domains and increasing its strength.

MAGNETS IN YOUR HOME

You'll be surprised at the number of magnets that are under your roof

Doorbell
For a buzzer-style doorbell, pressing the button moves and releases a contact from an electromagnet to break and complete a circuit. A chiming doorbell, meanwhile, moves an iron core through an electromagnet coil and back again when the button is pressed, hitting two chime bars in sequence.

Microwave
Inside a microwave oven is a magnetron, which contains magnets. Strong permanent magnets are mounted inside this tube. When electricity passes through the magnetron, the resultant electric and magnetic fields produce electromagnetic energy in the form of microwaves.

Vacuum cleaner
Electromagnetism is used here to produce the desired effect. A magnetically conducting material is inside the motor of the vacuum cleaner. When an electric current is introduced to a coil around the material, repulsive forces make the motor spin. The material loses its magnetism when the vacuum is turned off.

Computer
Like credit cards, the storage discs inside computers are coated with bits of iron. By changing the magnetic orientation of the iron, a pattern can be created to store a particular set of data. This pattern can be read by the computer, which replicates the data on screen. The monitor itself uses magnets in the same way as an old cathode-ray tube television.

Speakers
Using electromagnetism, most speakers contain a stationary magnet and a wire coil inside a semi-rigid membrane. When a current runs through the coil, the membrane rotates in and out because of the force between the coil and magnet, creating vibrations that produce sound. Phone speakers use this same mechanism, only smaller.

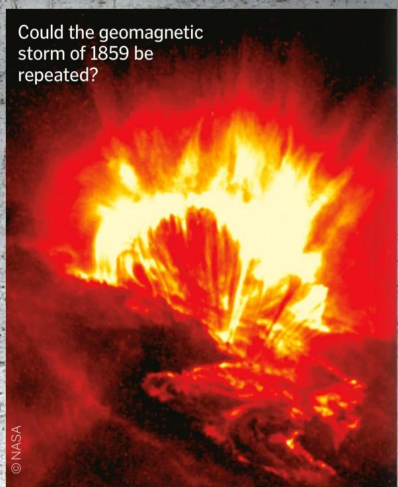
Credit card
All credit cards have a black strip on them, known as a magnetic stripe. Inside, minuscule bits of iron are held in a plastic film. These can be magnetised in a north or south direction to store important data. When you swipe the card through a machine, the line of tiny magnets is read and information is obtained.

Television
Most modern LCD or plasma TVs don't use magnets. However, older models use a cathode-ray tube to fire electrons against the back of the screen. Coated in phosphor, parts of the screen glow when struck by the beam. Coils produce magnetic fields that move the beams horizontally and vertically to produce the desired picture.

EMP
An electromagnetic pulse (EMP) works by overwhelming electric circuits with an intense electromagnetic field. A non-nuclear EMP explodes a metal cylinder full of explosives inside a coil of wire, pushing out magnetic and electric fields that fry electric circuits. A nuclear EMP would explode a nuclear bomb in the atmosphere. The resultant gamma radiation would take in positive air molecules but push out negative electrons, sending a large electromagnetic field in all directions. A ten-megatonne device detonated 320 kilometres above the centre of the US would destroy every electronic device in the country, but leave structures and life intact.


Buildings would survive; electronics wouldn't

Solar blackout


Could the geomagnetic storm of 1859 be repeated?

© NASA

In 1859 a great geomagnetic storm wiped out transmission cables and set fire to telegraph offices when the Sun went through a period of intense activity. Scientists at NASA warn that a similar storm could occur at the next solar maximum, with many more modern electrical components affected. The Sun's magnetic cycle peaks every 22 years, while every 11 years the number of solar flares hits a maximum. These events could combine and produce huge levels of radiation, potentially wiping out worldwide electric power on Earth for hours – or even days.

Human respiration

This physical and biochemical process transports oxygen from the air that surrounds us into the tissue cells of our body. It's absolutely vital to an organism's survival

The primary organs used for respiration in humans are the lungs. Humans have two lungs, with the left lung being divided into two lobes and the right into three. The lungs have between 300 and 500 million alveoli, which are where gas exchange occurs.

Respiration of oxygen breaks into four main stages: ventilation, pulmonary gas exchange, gas transportation and peripheral gas exchange. Each stage is crucial in getting oxygen to the body's tissue and removing carbon dioxide. Ventilation and gas transportation need energy to occur. The diaphragm and the heart are used to facilitate these actions, whereas gas exchanging is passive. Air is drawn into the lungs at a rate of between 10 and 20 breaths per minute while resting, through either your mouth or nose by diaphragm contraction, and travels through the pharynx, then the larynx, down the trachea and into one of the two main bronchial tubes. Mucus and cilia keep the lungs clean by catching dirt and dust particles and sweeping them up the trachea.

When air reaches the lungs, oxygen is diffused into the bloodstream through the alveoli and carbon dioxide is diffused from the blood into the lungs to be exhaled. This diffusion of gases occurs because of differing pressures in the lungs and blood. This is also the same when oxygen diffuses into tissue around the body. Once blood has been oxygenated by the lungs it is transferred around the body to where it is most needed in the bloodstream. If the body is exercising or under stress, the breathing rate increases, and consequently so does heart rate to ensure that oxygen reaches tissues that need it. Oxygen is then used to break down glucose to provide energy for the body. This happens in the mitochondria of cells. Carbon dioxide is one of the waste products of this, which is why we get a build up of this gas in our body that needs to be transported back into the lungs to be exhaled.

The body can also respire anaerobically, but this produces far less energy, and instead of producing carbon dioxide as a by-product, lactic acid is produced. The body then takes time to break this down after exertion has finished, as the body has a so-called oxygen debt.

How our lungs work

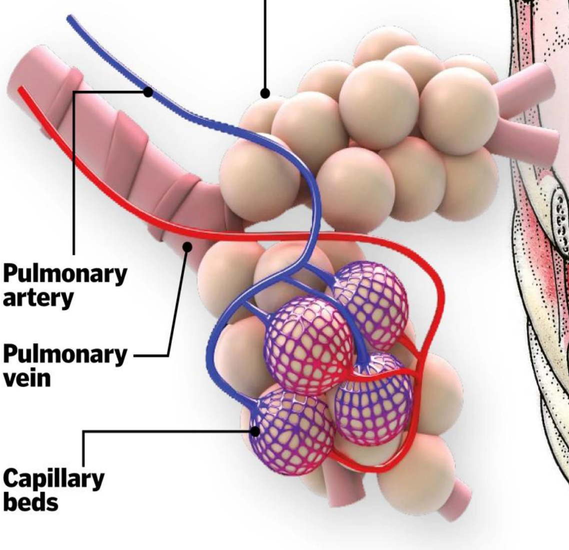
Lungs are the major respiratory organ in humans

1 Nasal passage/oral cavity
These areas are where air enters the body so that oxygen can be transported into and around the body to where it's needed. Carbon dioxide also exits through these.

2 Pharynx
This is part of both the respiratory and digestive systems. A flap of connective tissue called the epiglottis closes over the trachea to stop choking when an individual takes food into their body.

3 Trachea
Air is pulled into the body and then passes into the trachea.

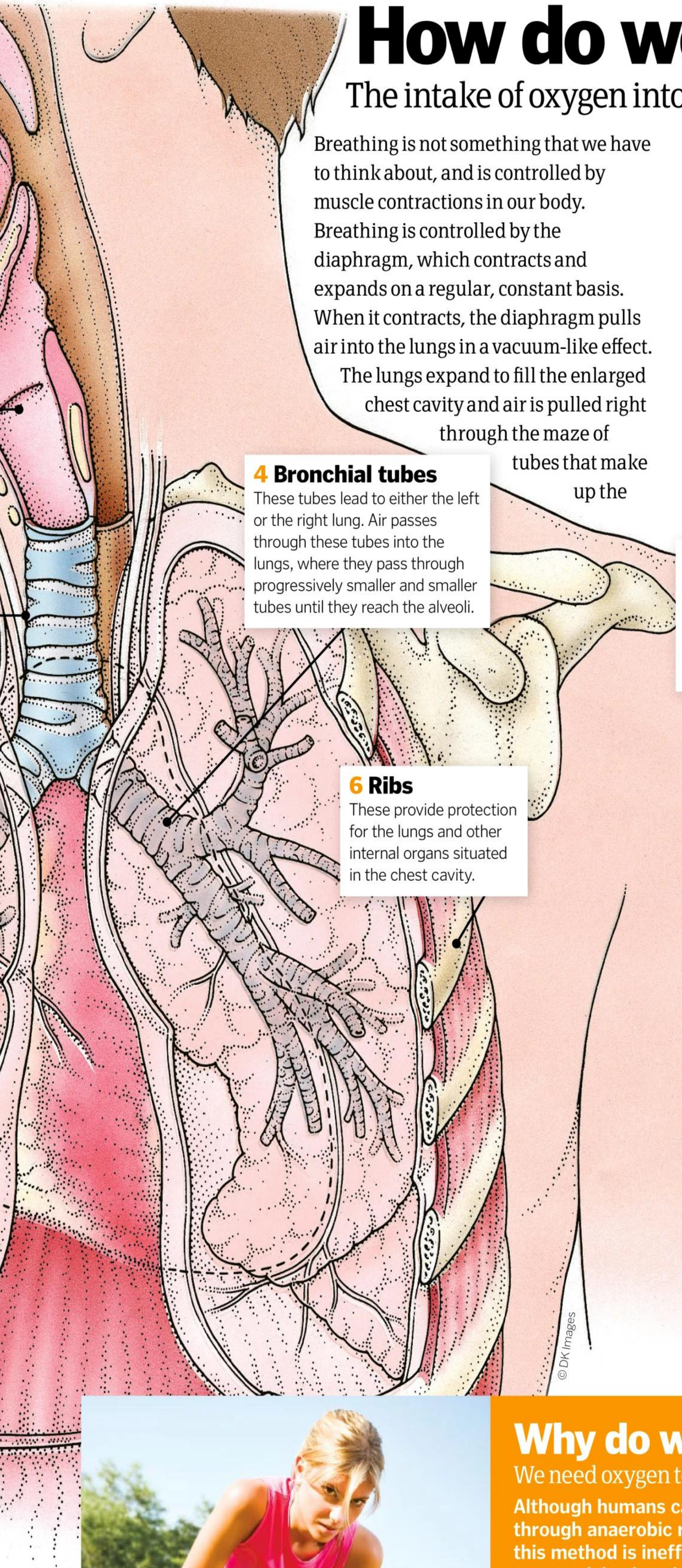
5 Alveoli
Alveoli are tiny little sacs which are situated at the end of tubes inside the lungs and are in direct contact with blood. Oxygen and carbon dioxide transfer to and from the blood stream through the alveoli.



How do we breathe?

The intake of oxygen into the body is complex

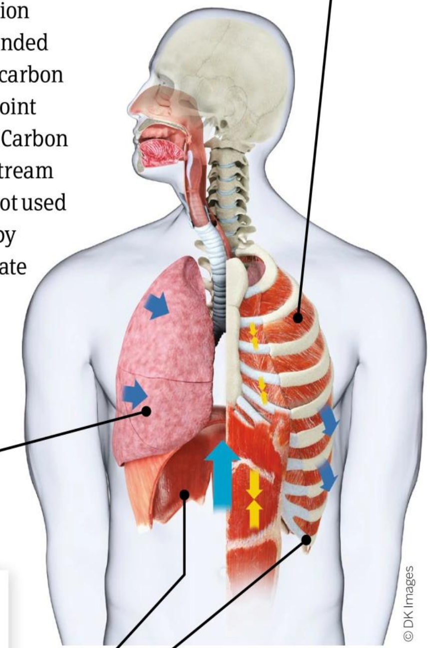
Breathing is not something that we have to think about, and is controlled by muscle contractions in our body. Breathing is controlled by the diaphragm, which contracts and expands on a regular, constant basis. When it contracts, the diaphragm pulls air into the lungs in a vacuum-like effect. The lungs expand to fill the enlarged chest cavity and air is pulled right through the maze of tubes that make up the lungs to the alveoli at the ends, which are the final branching. The chest is seen to rise because of the lung expansion when inhaling. Alveoli are surrounded by blood vessels, and oxygen and carbon dioxide are interchanged at this point between the lungs and the blood. Carbon dioxide removed from the blood stream and air that was breathed in but not used are then expelled from the lungs by diaphragm expansion. Lungs deflate back to a reduced size after breathing out.

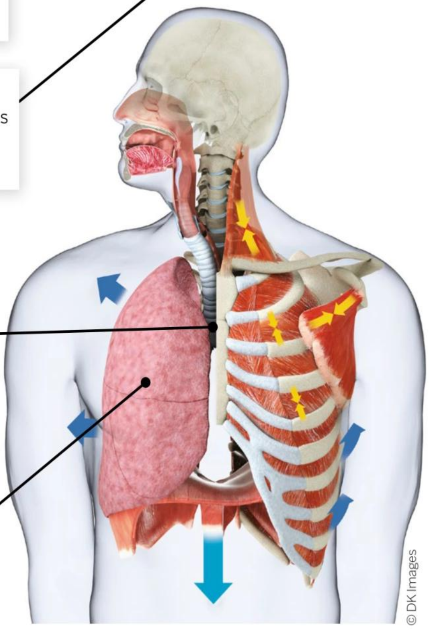


4 Bronchial tubes
These tubes lead to either the left or the right lung. Air passes through these tubes into the lungs, where they pass through progressively smaller and smaller tubes until they reach the alveoli.

6 Ribs
These provide protection for the lungs and other internal organs situated in the chest cavity.

© DK Images





Chest cavity
This is the space that is protected by the ribs, where the lungs and heart are situated. The space changes as the diaphragm moves.

Lungs
Deoxygenated blood arrives back at the lungs, where another gas exchange occurs at the alveoli. Carbon dioxide is removed and oxygen is placed back into the blood.

Diaphragm
This is a sheet of muscle situated at the bottom of the rib cage which contracts and expands to draw air into the lungs.

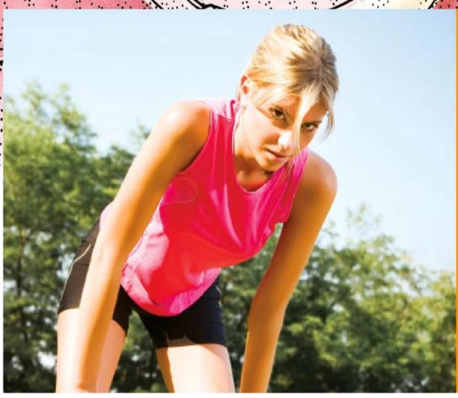
Rib cage
This is the bone structure which protects the organs. The rib cage can move slightly to allow for lung expansion.

Heart
The heart pumps oxygenated blood away from the lungs and round the body to tissue, where oxygen is needed to break down glucose into a usable form of energy.

Tissue
Oxygen arrives where energy is needed, and a gas exchange of oxygen and carbon dioxide occurs so that aerobic respiration can occur within cells.

© DK Images

© DK Images



Why do we need oxygen?

We need oxygen to live – it is crucial for the release of energy within the body

Although humans can release energy through anaerobic respiration temporarily, this method is inefficient and creates an oxygen debt that the body must repay after excess exercise or exertion has ceased. If the oxygen supply is cut off for more than a few minutes, an individual will die.

Oxygen is pumped around the body to be used in cells that need to break down glucose so that energy is provided for the tissue. The equation that illustrates this is:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

© Science Photo Library

Charge your gadgets, heat your home and even get paid for generating your own electricity

Renewable forms of power generation are becoming more and more essential. As the fossil fuels we currently rely on begin to run out, we need to find a replacement for the world's energy needs. The impact that burning oil and gas has on the environment must also be addressed if we are to stop and reverse the effects of global warming. One of the main forms of renewable energy that has entered the mainstream is solar power.

Capturing even a fraction of the Sun's energy that hits the surface of our planet could mean we are able to close our gas- and coal-fired power stations completely. The Sun emits solar radiation that is the equivalent of 1,367 watts of power per square metre. This is known as the 'solar constant'.

The Sun is a massive fusion reactor, pumping out its energy – 3.8×10^{26} joules per second – in all directions. Here on Earth we only feel a fraction of this energy. The Sun actually delivers about 7,000-times more energy to Earth's surface than we generate globally for human use at the moment. The tricky part is capturing that incredible energy and using it efficiently.

Solar cells are properly known as photovoltaics, as the process of converting light (photo) into electricity (voltage) is achieved within the photovoltaic cell. When sunlight hits the cell, which is usually made out of silicon, it makes electrons come loose from the atoms they are attached to. This action produces electricity. The more sunlight that hits the cells, the more electricity is produced, which you can then use to heat your water or charge your phone.

Across the world, every country is looking closely at how they can use more renewable energy sources. Unsurprisingly, solar power is most popular in countries lucky enough to get sustained periods of sunshine. Spain and Portugal have ambitious plans to develop more of their energy generation via solar power, while India leads the way with three of the top five of the world's largest solar power stations.

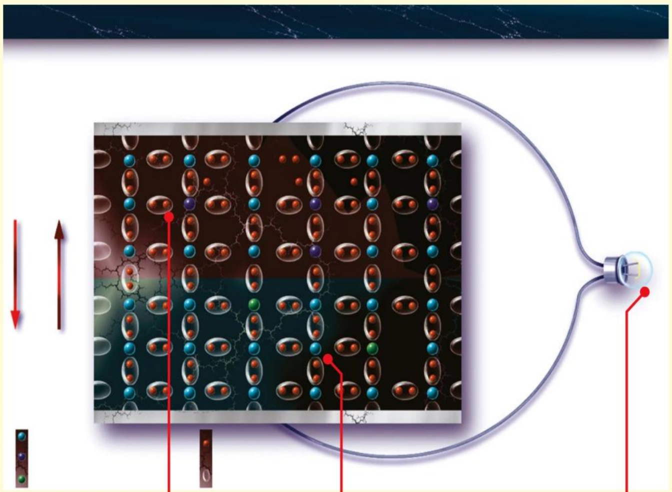
All this talk of solar energy and the fact that the Sun delivers much more energy than we need should be put into context – we don't yet have highly efficient solar cells to harness the free energy. If you compare the output of your gas boiler to that of currently available solar cells, they're only around 20 per cent efficient.

However, this is still a massive leap forward from the three to five per cent efficiency that the earliest solar panels could manage. The race is now on to develop more efficient photovoltaic cells, which will let us capture more of the Sun's precious energy. Current research is looking at organic photovoltaics, nanotechnology and even the ability to print solar cells onto just about any surface.

Photovoltaic cells in action

What goes on inside a solar cell on an atomic level?

If the Sun isn't shining

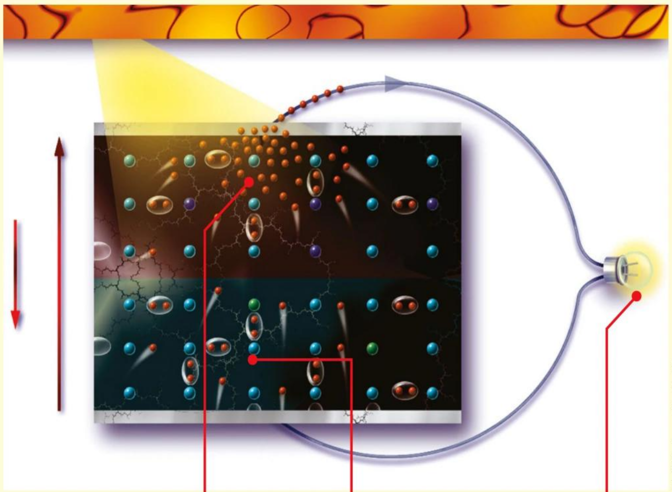


1 Atoms are not excited
No sunlight means the atoms remain at rest.

2 Sunshine will excite the electrons
Electrons will only break free when sunlight excites their parent atoms.

3 No electricity is produced
Without free-moving electrons, electricity can't be generated.

If the Sun is shining



1 Electrons set free
Sunlight agitates the atoms until their electrons are set free.

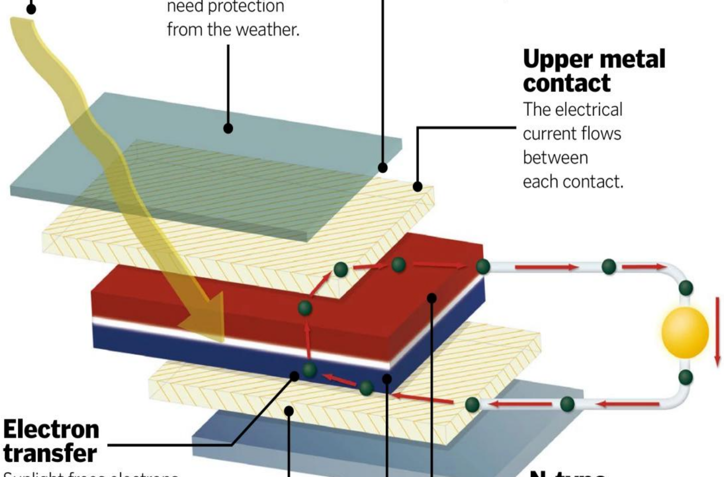
2 Some atoms will remain attached
Not all of the atoms need to be dislodged to create electricity.

3 A circuit is made and electricity is produced
The metal contacts make the circuit that illuminates the bulb.

This photovoltaic barrier was built in 2001 in Freising, Germany

How solar cells work

A layer-by-layer breakdown of what's in a solar cell and how the different parts work



Sunlight

Glass cover
Photovoltaic cells need protection from the weather.

Anti-reflection coating
The anti-reflection coating ensures sunlight is absorbed by the photovoltaic cell.

Upper metal contact
The electrical current flows between each contact.

Electron transfer
Sunlight frees electrons from their parent atoms and generates electricity.

N-type (negative) silicon
Impure silicon is used to create the negative part of the circuit.

Lower metal contact
Electrical current is captured between the upper and lower contacts.

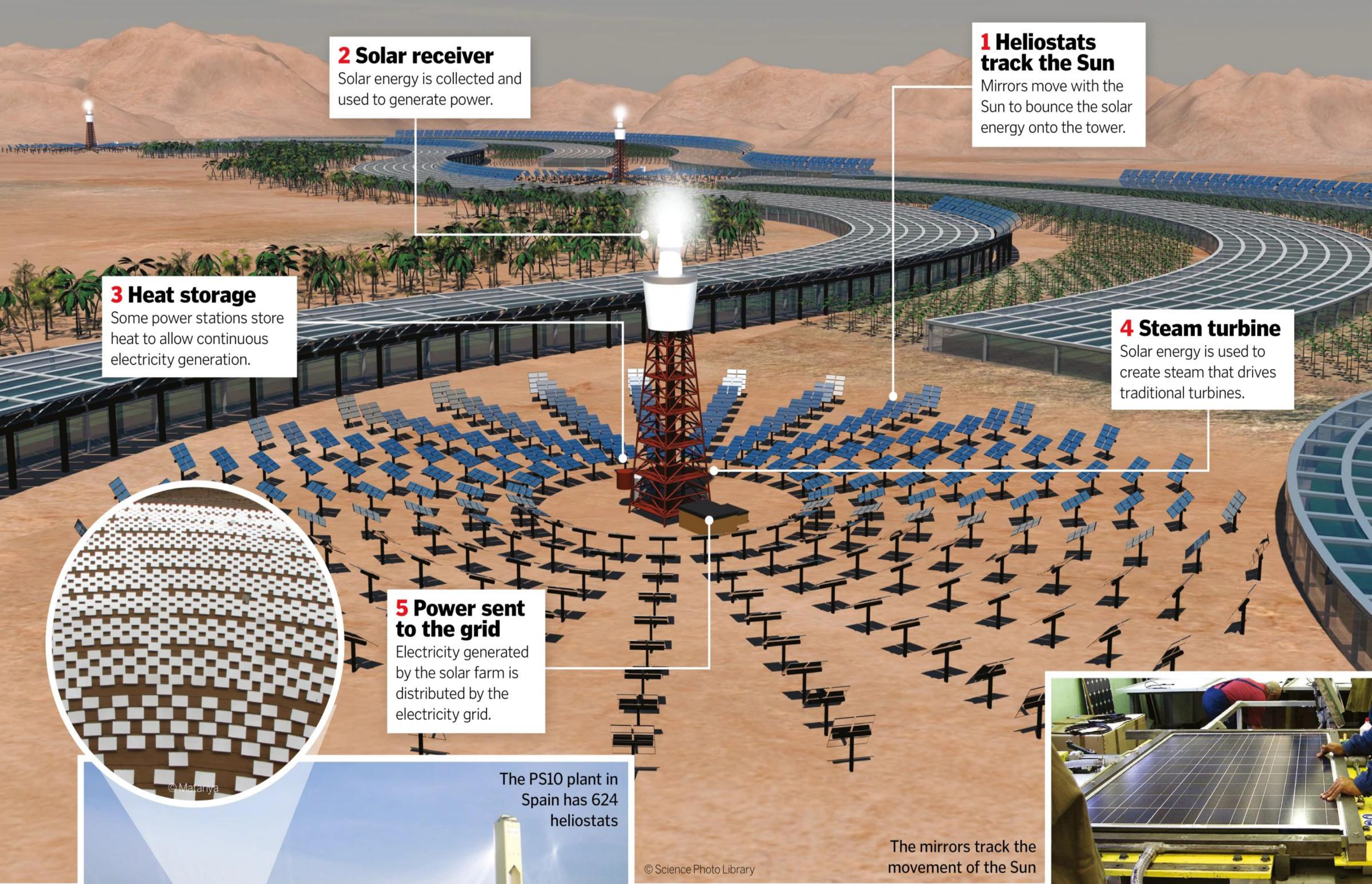
P-type (positive) silicon
Silicon with boron impurities creates the positive component of the circuit.

Solar power stations

Generating large amounts of power needs more than a few panels. Solar power stations generate electricity by creating steam that drives a turbine. The power to heat the water comes from the Sun.

Solar power stations use a series of computer-controlled mirrors called heliostats that track the movement of the Sun and reflect its energy onto a solar receiver on top of a tower at the centre of the station. The tower contains a boiler where the water is heated. Steam is then piped to steam turbines that generate the electricity fed into the grid for distribution.

Some more advanced solar power stations also divert some of the steam generated and store this for future use. This allows the power station to stay operational even at night, or when adverse weather conditions prevent the power station from working at full capacity.



The mirrors track the movement of the Sun

The PS10 plant in Spain has 624 heliostats

The panels come in all shapes, sizes and formations

ON THE MAP

World's biggest solar farms by megawatt capacity

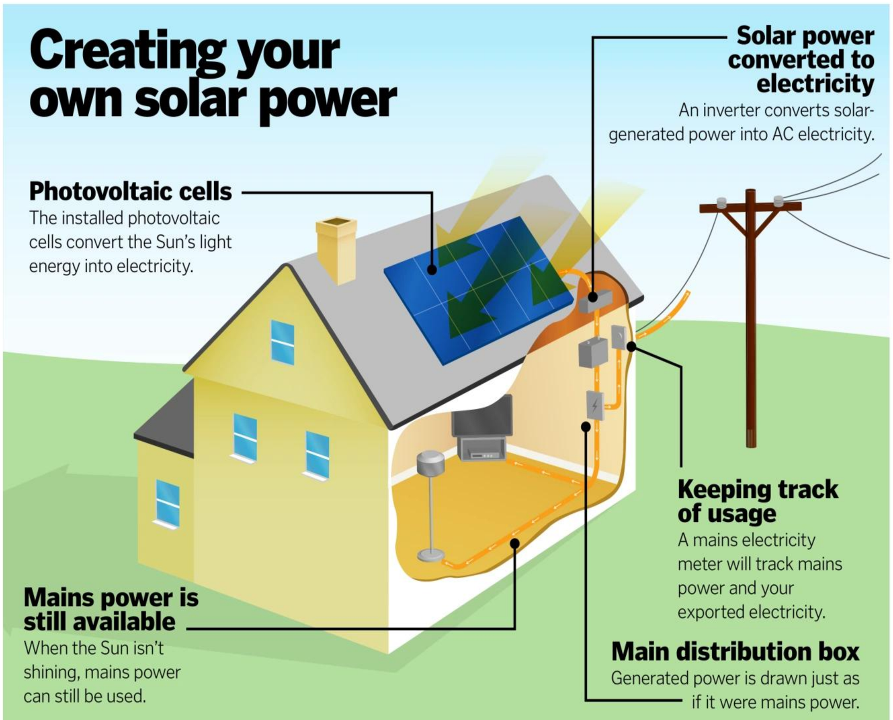
1. Shakti Sthala: 2,000 MW
2. Kurnool: 1,000 MW
3. Longyangxia: 850 MW
4. Kamuthi: 648 MW
5. Noor Complex: 580 MW

How to make and sell your own electricity

One of the great things about installing solar panels at home is that you can sell any surplus electricity you generate to your local electricity supplier. The smart export guarantee, or SEG, enables energy to be sold back to the grid, monitored by a smart meter.

Under the SEG scheme, your local electricity company is required to establish export tariffs to demonstrate to customers how much money they will get per unit of electricity exported. When the photovoltaic cells of your solar panels generate more power than you can use, the extra can be sold to your electricity supplier at an agreed rate. In the UK this is up to 5.6 pence per kilowatt hour (kWh) with certain energy suppliers.

The practical upshot of SEG for anyone who installs solar panels and produces any excess is that they will receive a payment from their electricity company on an annual basis. The photovoltaic system that you install works with a meter that not only measures how much electricity you are using from the mains supply, but also what you are generating. This is how the electricity company can calculate your payments.



Living off the grid

Life without the basic utilities might sound like a nightmare for some, but for an increasing number of people, living 'off the grid' has become a lifestyle choice. These people have not simply installed a solar panel or two, but chosen to remove themselves completely from the tether most of us have to the grid and the other utility providers.

As you would expect, compromises have to be made. The amount of electricity you can generate will be dependent on the sunshine you receive, and of course there will be no long showers, nor running massive fridges when you're living off the grid.

The power that is generated is usually stored in batteries for later use, and to ensure some electricity is available when the Sun is absent. As photovoltaic cells can be attached to just about any structure or used free-standing, they offer anyone who wants to live off the grid a readily available source of power.


© NASA

INTERVIEW

DuPont senior research fellow Dr Bill Borland

What is the state of the solar power industry today? Has its uptake in businesses and homes been increasing?

The growth of solar power has been very impressive over the last few years, but it still represents less than one per cent of global electricity production. The adoption of solar power by homes and business is primarily driven by government subsidies – being 'green' is an added attraction.

Europe, particularly Germany, has had attractive subsidies in the form of feed-in tariffs that have promoted tremendous growth in homes and businesses. Growth in other nations, such as the US, is emerging, primarily from business rooftop installations.

Could you describe the process of making solar cells?

The fabrication of a conventional crystalline silicon solar cell starts with texturing one side of a boron-doped silicon wafer that will become the front face. The wafer then undergoes a high-temperature phosphorus diffusion process to form the P/N junction. After removing phosphorus silicon glass, a by-product of the diffusion process, a silicon nitride anti-reflection coating is applied to the front face. This is followed by screen-printing silver paste on the front and aluminium and silver tabbing pastes on the back. The silver and aluminium pastes are rapidly co-fired to form the completed cell.

How do current solar cell technologies differ from those used in the past, specifically with regards to efficiency?

Today's six-inch monocrystalline industrial solar cell comprises a textured and passivated front face, screen-printed silver contacts and a complete metal coverage at the back. The first cell in 1953 had an efficiency of 4.5 per cent. In 1960, with the introduction of the front finger grid, efficiency leapt to 14 per cent. Full metal coverage of the back in 1972 and texturing in 1974 raised the value to 17 per cent. In 1975 screen-printed contacts became common. Wafer sizes, however, were two to three inches. Since 1975, effort in increasing wafer sizes to six inches, silicon nitride passivation in 2002 and improved contacts have created today's 20 per cent efficient solar cell.

Are there any upcoming technologies that will improve the efficiency of solar cells?

The drive-to-grid parity demands improved efficiencies without increasing cost. This means changes to the conventional solar cell. Technologies like selective emitters and rear surface passivation are expected to become mainstream, and each can raise efficiency by up to one per cent.

Technologies on the horizon include the use of N base cells instead of P base cells. N base cells are more tolerant to impurities, making them resistant to light-induced degradation of efficiency. Other developments include metal wrap through and all back contact cells, which could deliver efficiencies greater than 20 per cent.

Gold mining

From impervious rock to precious metal, how is gold extracted and processed?

Gold has been sought after worldwide for centuries due to its value to the economy, not to mention its intrinsic beauty. Its face-centred cubic crystal structure and soft and malleable nature mean that it is the foremost material used in the jewellery industry, being shaped into a wide variety of decorative items. Unfortunately, while handling gold is easy, acquiring it is not, with numerous highly scientific processes and technological machines needed to find, mine and process it.

Native gold – as found within gold ores – occurs both at Earth's surface (exogenetic) and underground (endogenetic), with each iteration requiring differing techniques to acquire and process it. The majority of exogenetic gold exists as alluvial gold deposits. Alluvial gold is that found in riverbeds, streambeds and floodplains, where surrounding rock and metals from its ore have been washed away. This type of gold is processed by passing deposits over jigging conveyor belts, which free the denser gold from the less dense sand and gravel.


Gold is extracted and refined using two main methods

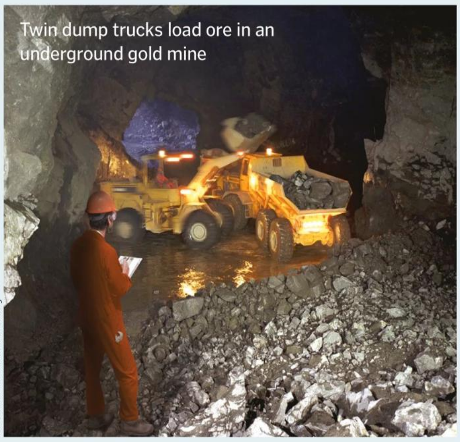
© Rob Lavinsky, iRocks.com

Unlike the easily accessed exogenetic alluvial deposits, endogenetic deposits are much harder to extract and process. This is because endogenetic deposits often contain elemental gold finely disseminated within a base metal sulphide material. It's literally encapsulated within a rocky prison – the ore. To free this fine particulate gold, two main methods are used: amalgamation and cyanidation.

Amalgamation works by passing a slurry of ore over copper plates coated with mercury. By doing this the elemental gold is wetted and dissolved, forming an alloy called 'amalgam'. The amalgam is then separated from the now-barren ore in a mill discharge before being heated to distil off the mercury, leaving nothing but the now-free gold.

The cyanidation process is similar to amalgamation, but a little more complex. Here the gold ore is oxidised and dissolved in an alkaline cyanide solution. This process results in the formation of sodium cyanoaurite and sodium hydroxide and allows a gold-bearing solution to be separated from the worthless ore solids.

Refining gold is a necessary step to ensure purity, as extracted endogenetic gold commonly contains a number of impurities such as iron and copper. As with the extraction process, it relies on two main methods: the Miller process and the Wohlwill process. The Miller process involves the extracted gold being melted and mixed with gaseous chlorine. This causes the impurities in the gold – which bond more easily with the chlorine than the gold does – to form chloride compounds that separate into a layer on the gold's surface. These are then easily removed. The Wohlwill process, meanwhile, uses electrolysis to achieve a separation of impurities. Gold is lowered into an electrolyte solution and an electric current is passed through. Under the influence of the current, the impurities pass into it and sink to the bottom of the tank as an insoluble slime, leaving the gold free and pure.


Twin dump trucks load ore in an underground gold mine

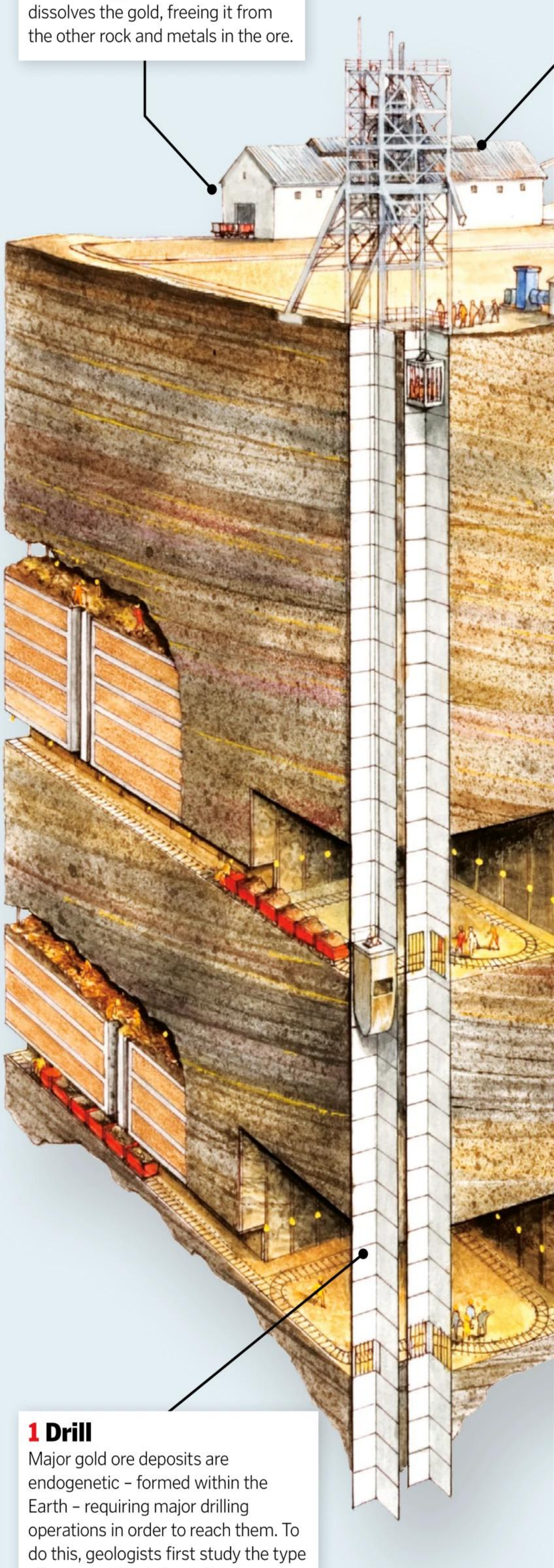
© Science Photo Library


The Grasberg gold mine in Papua, Indonesia, is the largest in the world, covering 27,400 acres

© Afindra Primaldhi

4 Processing

Once the deposits are brought to the surface, the ore is ground into a fine powder and added to a cyanide solution. The solution – combined with the oxygen in the air – dissolves the gold, freeing it from the other rock and metals in the ore.



1 Drill

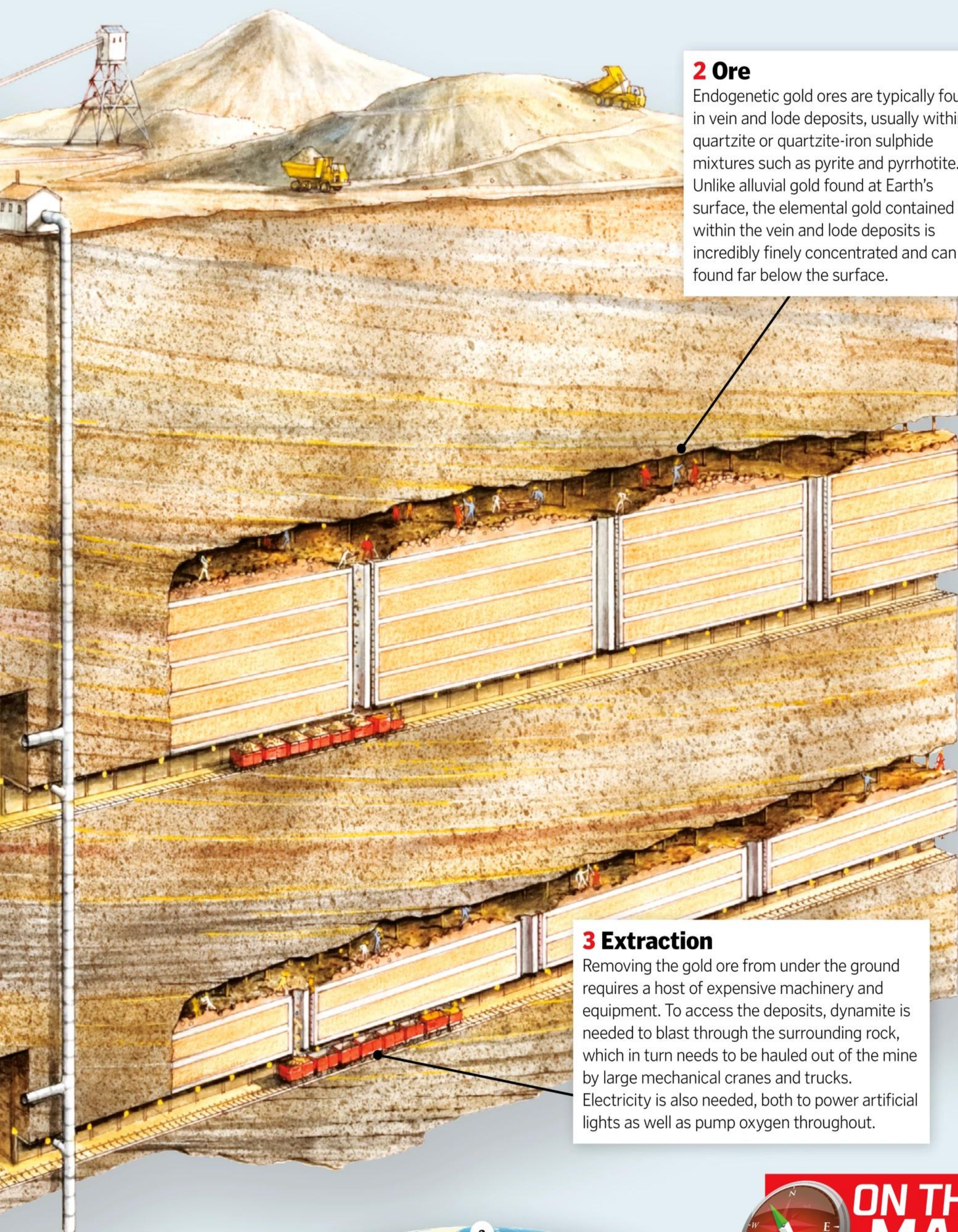
Major gold ore deposits are endogenetic – formed within the Earth – requiring major drilling operations in order to reach them. To do this, geologists first study the type of rocks and their formation in a certain area, looking for telltale clues. Once an area is designated, multiple diamond drill cores – thin, cylindrical samples – are taken and studied. If gold or gold-related materials are found, a larger access hole is created.

Underground gold mining

Discover the five key stages in acquiring one of the most precious metals our planet has to offer

5 Refine

Gold extracted by amalgamation or cyanidation contains impurities. To remove these, two methods of refining are used. The first uses chlorine gas to filter out the gold's impurities, bonding with them once the gold is melted. The second method uses electrolysis, turning the impurities into insoluble slime.



2 Ore

Endogenetic gold ores are typically found in vein and lode deposits, usually within quartzite or quartzite-iron sulphide mixtures such as pyrite and pyrrhotite. Unlike alluvial gold found at Earth's surface, the elemental gold contained within the vein and lode deposits is incredibly finely concentrated and can be found far below the surface.

3 Extraction

Removing the gold ore from under the ground requires a host of expensive machinery and equipment. To access the deposits, dynamite is needed to blast through the surrounding rock, which in turn needs to be hauled out of the mine by large mechanical cranes and trucks. Electricity is also needed, both to power artificial lights as well as pump oxygen throughout.

© DK Images

ON THE MAP

Top ten gold-producing countries in 2019

1. China – 383.2 tonnes
2. Russia – 329.5 tonnes
3. Australia – 325.1 tonnes
4. US – 200.2 tonnes
5. Canada – 182.9 tonnes
6. Peru – 143.3 tonnes
7. Ghana – 142.4 tonnes
8. South Africa – 118.2 tonnes
9. Mexico – 111.4 tonnes
10. Brazil – 106.9 tonnes

Panning for gold

How to perform the oldest mining technique in the book

STEP 1
Locate gold country

Locating a 'gold' area requires a study of geography and geology. Riverbanks and streams are good places to start, as placer deposits can form in them during sedimentary processes. These deposits contain alluvial gold, which forms in the rivers and streams due to their low

STEP 2
Knead

Once a gold area has been located, take your gold pan and submerge it, scooping up part of the riverbed. Once filled with debris, knead the contents to break it up fully and ensure the materials are saturated with water. A lot of mud and silt will rise to the surface and get washed away, as well as any leaves and roots.

STEP 3
Shake, shake, shake

Once the pan's contents are saturated, grip it in both hands and shake it from side to side just under the water's surface. You'll break down the contained materials further, freeing them of dirt and miscellanea as well as causing the heavier materials to sink to the bottom. Any overly large objects such as rocks will also stand out from the debris. When this happens, remove them from the pan by hand.

STEP 4
Rinse and repeat

Continue to shake the pan and sweep the top layer of materials away. The remaining materials should get smaller and darker until you're left with a dense, black sand. This consists of the heaviest materials left in the pan. This is the point to check how rich the area's gold content is. Taking a little bit of water in the pan, gently swirl the materials. This will cause any gold at the bottom to become visible.

STEP 5
Harvest

If flakes or small nuggets of gold are present, drain off the water and apply a magnet to the sand. This will help remove the worthless metals and reduce the black sand covering the gold. Finally, once the gold flakes or nuggets are visible, use a pair of tweezers to place them in a collecting jar.

Electrical plugs and wall sockets

How your gadgets are connected to the mains safely

Electrical plugs provide users with a physical, easy-to-handle plastic connector that acts as a bridge between an electrical appliance's power cable and the mains electrical grid. Plugs come in a variety of shapes and sizes – as do their equivalent sockets – but all share a couple of basic characteristics and a selection of standardised technology.

Each plug has either two or three separate wired contacts, each of which is contained within a thick, insulated cable. These contacts are commonly made from steel or brass, as they are good conductors, and coated with zinc and nickel. The first contact is referred to as the 'line' or 'live' contact and terminates at the live terminal at the right-hand side of the plug. The live wire carries current from the source to the load and vice versa, as the predominating form of electricity delivered to households is alternating current (AC), where the current changes direction up to 60 times per second.

The second wire is referred to as the 'neutral' contact and terminates at the neutral terminal, which is positioned parallel to the live terminal on the left-hand side of the plug. This contact completes the circuit running through the load in order to generate the necessary power to run it. As with the live contact, current from the source frequently enters and exits the load multiple times per second via the neutral contact. However, unlike the live contact it remains at the voltage potential of the third wired contact, the 'earth'.

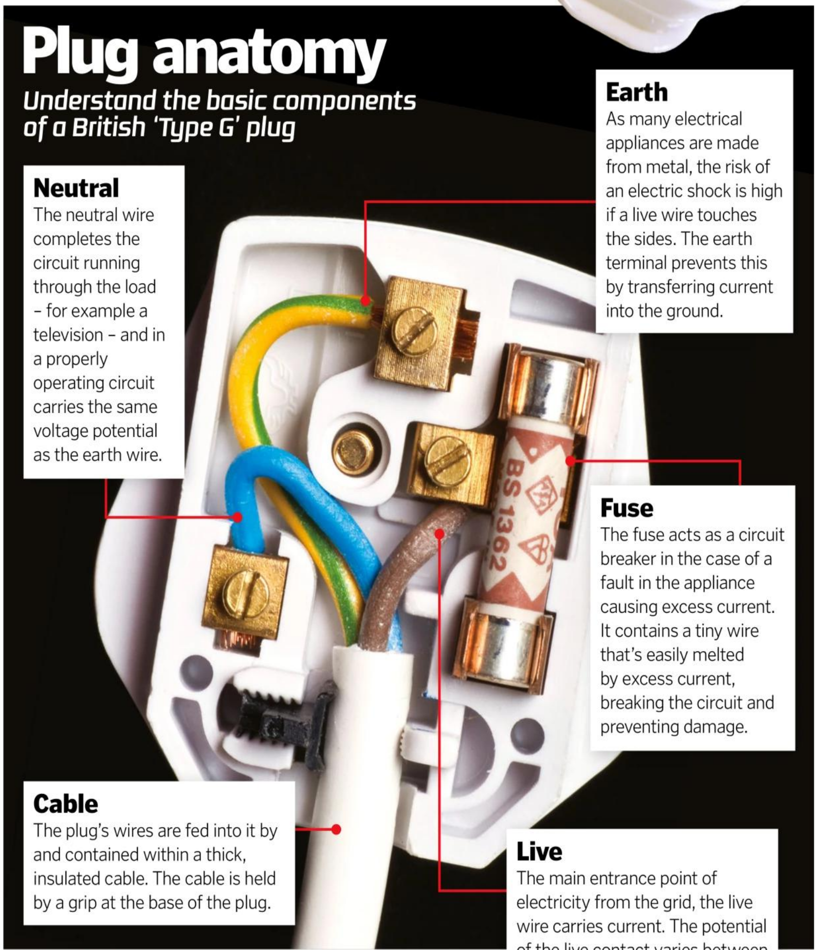
The earth contact is a feature of three-pin plugs and terminates at the earth terminal at the top of the plug. The earth contact is a safety device used to protect against an insulation failure of the live wire, such as the live wire touching the metal casing of an electrical appliance. This means that if a failure occurs, any potentially dangerous voltage is passed from the electrical system to one or more earthed electrodes instead of directly into the user.

In some plugs, such as the British 'Type G', a fuse is also present. This is an added safety feature to ensure that excess current doesn't flow through the plug and the appliance. The fuse is located between the live terminal and the live pin and consists of a cylindrical tube fitted with a tiny, easily melted wire, with contacts at each end. If excess current flows through the fuse, the wire melts and the circuit is broken.

Plug sockets are designed to partner a region's chosen plug standard. Sockets, along with certain plugs, can be polarised. Polarisation of sockets and plugs ensures that devices cannot be connected the wrong way round, with the live and neutral pins interchanged. In the majority of products this would not cause an issue, as the circuit would still be complete. However, if live was connected to neutral and vice versa in products such as toasters with exposed metal elements, a different outcome would occur. When the user turned them off, their internal wiring would still remain active, causing an electric shock if tampered with.

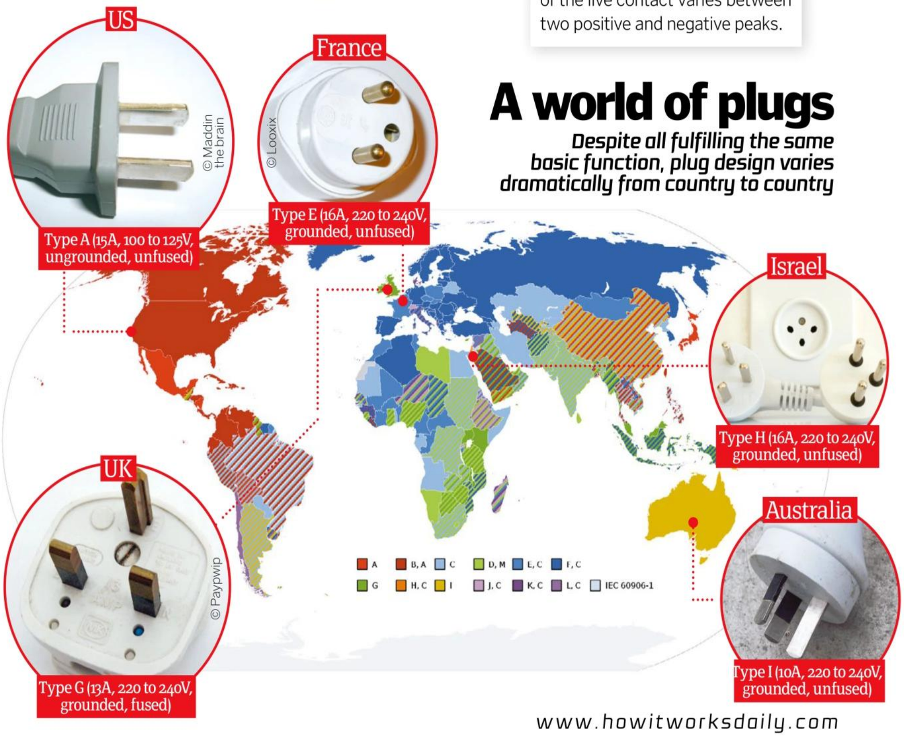
Plug anatomy

Understand the basic components of a British 'Type G' plug



A world of plugs

Despite all fulfilling the same basic function, plug design varies dramatically from country to country



THE ROAD TO ELECTRIC VEHICLES

Discover how battery power is transforming driving as we look inside an all-electric car

Words by **Ailsa Harvey**

In today's world we always have somewhere to be, and many of us rely on cars to get us there. These vehicles have been around since the late 1800s, and they are on their own evolutionary journey. From the clunky early models that only needed to transport people from A to B to be deemed successful, to today's more environmentally friendly vehicles, car companies are always looking towards the next best thing. One of their main focuses is removing the old engines of these vehicles and providing sustainable but desirable electric cars.

Going electric doesn't necessarily have to mean making a dramatic energy swap. In fact, there are three main types of electric vehicle, with only one completely removing the engine component from the car.

This battery electric vehicle, commonly known as fully electric, is for people who have committed to a new era of driving. Their high-capacity battery packs provide enough energy to drive the car as well as run all internal electronics. Fully electric cars are the only type of e-car to produce zero greenhouse gas emissions, and they allow a DC fast charge.

Plug-in hybrid electric vehicles act as a transition between fossil fuel and electric power. With both a small electric motor and a conventional engine, they can travel short distances at low speeds on electricity before the engine kicks in. The battery in these cars is charged through a plug and socket, like the fully electric vehicles. Finally, the hybrid electric also uses both power sources. The difference between this and the plug-in is that the electric energy it uses is generated by the heat given off by the car's braking system.

Car company Honda's solution to an electric future is the Honda e. As Honda's first fully electric launch, it's aimed to suit a city commute, with a maximum travel range of 220 kilometres, or 137 miles, per charge. Tackling an area most impacted by traffic-heavy roads, new electric cars like this could be a progression towards healthier cities and quieter streets.

Driving innovation

How these cars suit the modern world

1 Happy planet Swapping to electric transport contributes to better air quality as there are less greenhouse gases. All-electric vehicles produce no exhaust emissions.

2 Cheap to run Per kilometre, electric vehicles cost about a third of the price to charge than it would to buy petrol for them. Electric motors also require less maintenance.

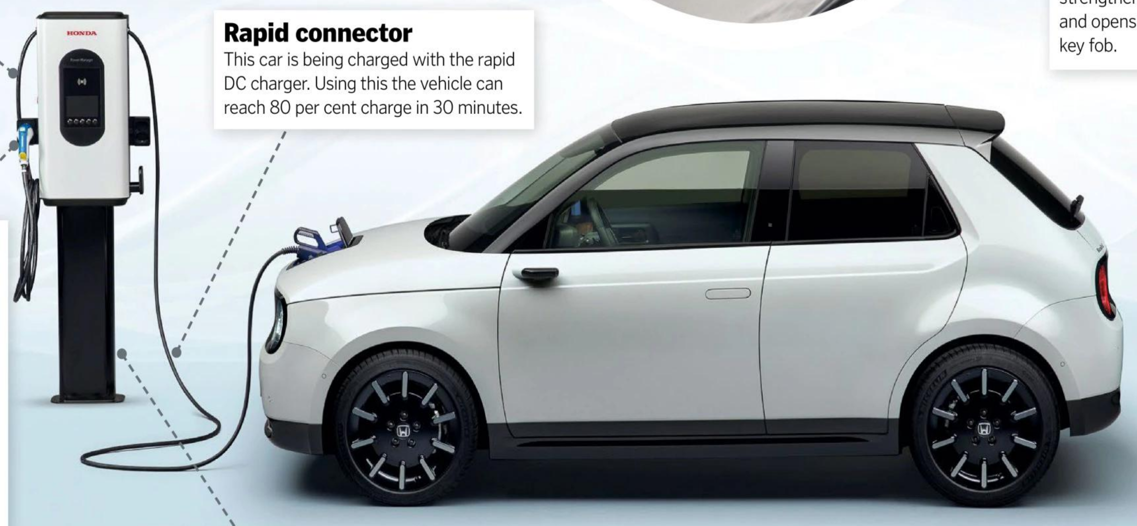
3 Noise reduction Without a roaring, fuel-driven engine, electric cars usually only produce tyre noises and the sound of wind resistance.

4 Safer drive As their motors are smaller than petrol or diesel-engined cars, their centre of gravity is shown to be lower. This makes them less likely to roll over.

5 At-home charging Cutting out the dash to the petrol station, electric cars can recharge while parked at home. This makes the process easier and more reliable.

How to recharge

Prepare your e-car for the road ahead



Choice of charge
The Honda e can either be slow, fast or rapid charged using the different connectors to supply a range of wattages. These are available at many public charging points and provide an option for fast and more frequent charging or a slower process with long-lasting power.

Status indication
This is an LED strip programmed to change colour based on the power status. When charging begins the light will turn blue, while red indicates an error. The light can be seen when approaching the car, even when the charging port is closed.

Charging port
Being in the centre of the bonnet, rather than on one side, makes the port more accessible. The car can be charged from either side or standing in front of the vehicle. The lid is made of strengthened glass and opens using the key fob.

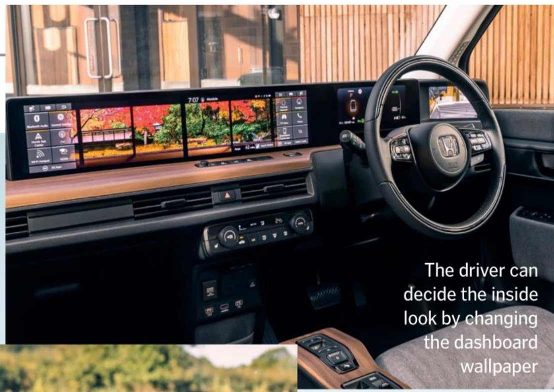
Rapid connector
This car is being charged with the rapid DC charger. Using this the vehicle can reach 80 per cent charge in 30 minutes.

Type 2 connector
This type of connection can be used when charging the vehicle at home or at public charging points. When using 'fast-charging' mode, bringing the battery from 0 to 100 per cent will take roughly four hours, while on slow charge this will take about 12 hours. The cars are very rarely charged from a completely drained battery.

Combined charging system
This charging station can provide the driver with a choice of AC or DC charging. The AC connector allows slow and fast charging options, while the DC provides efficient rapid charging. The Honda e's charging inlet is shaped to fit both connectors.

INSIDE THE HONDA E

Meet the new, compact city car driving away from petrol and into the electric era



The driver can decide the inside look by changing the dashboard wallpaper

The panoramic aquarium is an extra feature which can be used while parked. It provides a calming lounge-style atmosphere, and you can virtually feed the fish by touching the screen

Digital dashboard

The dashboard is filled with electronic technology that's powered by the car's battery. It includes five screens to display apps and other features that aid driving. The car can also be connected to a smartphone to display music apps and contacts for in-car calls. Videos and films can only be viewed when stationary. A screen near the driver and one by the passenger can be switched so that tools for navigation and those for entertainment are nearest to the person benefitting from them.

Visualising power

Just as a petrol- or diesel-powered car displays how much fuel is left in the tank, behind the steering wheel a screen shows what percentage of charge is left in the battery. This gauge will tell you how many miles you have left and will alert you with visual warnings when it is getting low. When you receive this alert, there is still enough time to drive to the nearest charging point.

Cameras for mirrors

Wing mirrors are replaced with sleek and subtle cameras. The goings on from all around the vehicle can be monitored in front of you. These cameras stream live video footage onto screens at the edges of the dashboard and are positioned to minimise any blind spots. By having them inside the car rather than behind the windows, views are clear in all conditions. If cars approach too close from the sides, the camera footage will display distance lines to better inform you of how much space lies between the vehicles. When darkness falls, the Honda e's cameras adapt to night vision, maximising your visibility of the roads. They also feature glare resistance, preventing headlights behind you from limiting your vision.

© Honda

The mirrors stick out for a wide view, but have a flat shape to remain aerodynamic

Car in your palm

The electric element isn't the only aspect of this car showing 21st-century changes. The MyHonda+ smartphone app serves as a remote car operator and tracker. By logging into the app you can lock and unlock the car, view the battery status and stop and start the charging process remotely while it is parked at your house. By providing a phone notification when the car reaches 15 per cent charge, drivers can be assured that they won't get caught short of power. Smartphone apps have proven successful for electric car owners to monitor their car, especially if they aren't used to having an electrically powered vehicle, as well as searching for public charging stations nearby.

The app acts as additional security, telling you where your car is and if it's locked

© Honda

When the key fob is close, the car picks this up and the door handle pops out as the door unlocks

Leading the charge

As most major car manufacturers are beginning to steer towards an electric future, many are envisaging how recharging these vehicles can be made more accessible. With lamp posts already lining most streets, one plan involves incorporating charging points into them. In the future the journey to a charging station could be as simple as pulling over at the side of any road. This system is already being trialled in cities such as London and Berlin.

There are 700,000 lamp posts in London alone, already connected to electricity

© Honda/Ubitricity

Parking assistance

Have you ever reversed into a space and needed your passenger to get out and guide you as you park? Taking over this role in the Honda e is the Parking Pilot. The sonar and camera technology can be used to better inform you of nearby objects and alerts you when you drive too close. On the display, an aerial view diagram of the car shows your position relative to surrounding objects. This helps the driver to view all the space around them at once, helping them park safely and with confidence.

Another option is to let the car park itself. By pressing the parking button, the car's four cameras and 12 sonar sensors scan the area for a suitable space. The cameras look for white parking lines on the road, while the sonar sensors check that there are no obstructions. The car completes this manoeuvre without the driver touching the steering wheel, gears, accelerator or brake.

Battery power

The 35.5 kWh lithium-ion battery keeps the car running on electricity up to 137 miles on a single charge. To optimise performance it has a thermal management system which adapts to heat or cool the battery in fluctuating conditions.

4.3 metres

The distance needed for the Honda e to perform a U-turn – this improves navigation on narrow streets

2030

Honda predicts that in ten years' time all cars will be focused on electrification, automation and connectivity

2022

Honda's goal for all its mainstream models in Europe to be electrified

50%

Wing mirror cameras increases the field of vision by half

8.3 seconds

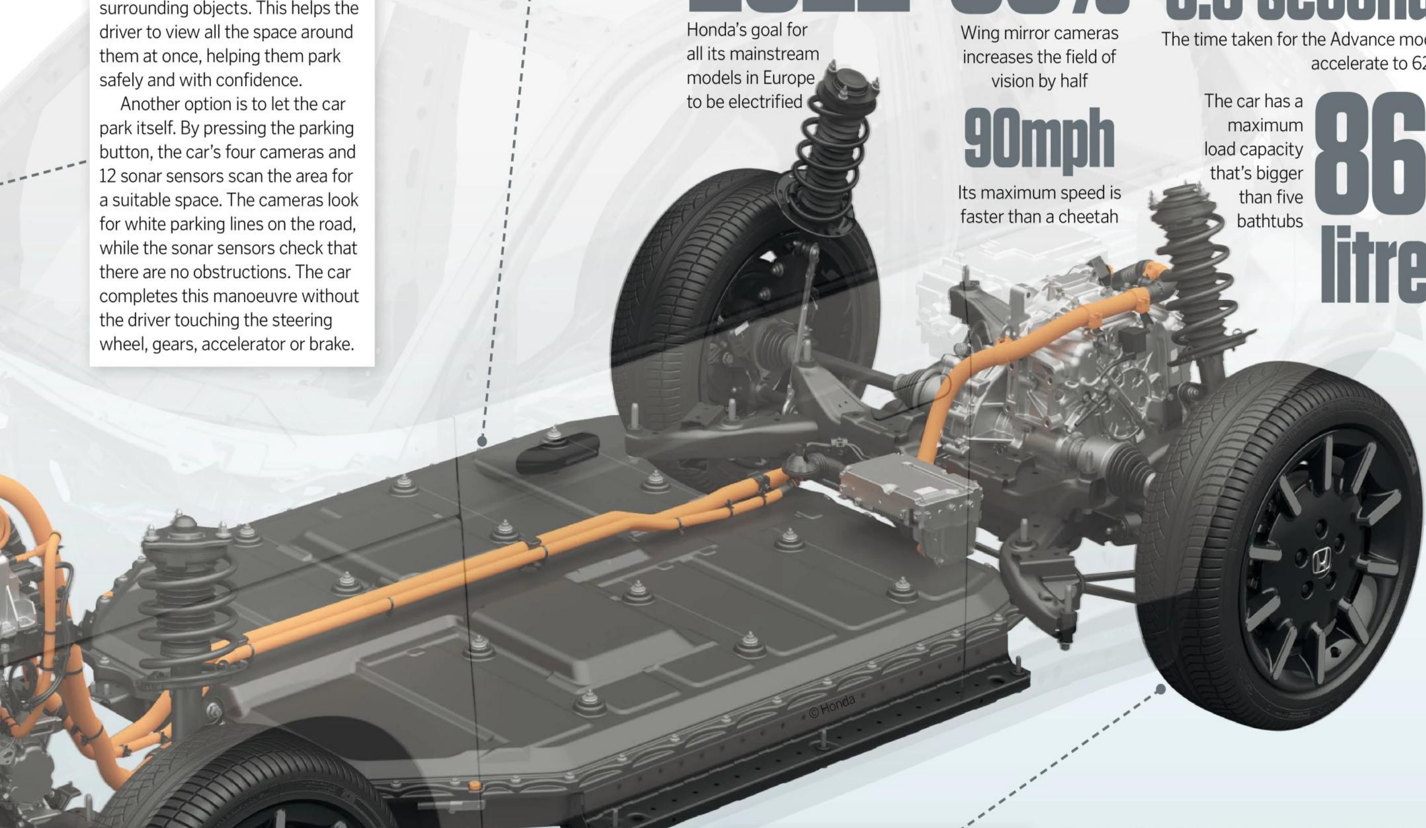
The time taken for the Advance model to accelerate to 62mph

90mph

Its maximum speed is faster than a cheetah

861 litres

The car has a maximum load capacity that's bigger than five bathtubs



© Honda

Strong core

For driving around the tight corners of cityscapes, the Honda e is designed with a 50:50 weight distribution and a low centre of gravity, placed 50 centimetres from the ground. The strong-but-lightweight chassis also comes with independent suspension. At its edges, protective panels protect the car's battery from any side collisions.

Rear-wheel drive

Installed to improve handling, the car's power is also sent to the back wheels. This helps to make driving feel more balanced and powerful. As more electric cars appear on the market, we could see the end of front-wheel drive. Their motors are relatively small compared to the engines of gas-powered cars, making them easier to mount at the front, back or both ends of the vehicle. In the Honda e, power at the rear improves the electric driving experience. Without having a heavy engine near the front, the back is where the weight of the car is pushed to during acceleration.

© Honda

'Sport mode' uses rear-wheel drive, aiding increased responsiveness

How a coronavirus test site works

These army medical centres test patients in their thousands

Words by **Ailsa Harvey**

People in the armed forces are used to serving their country. However, in recent months they have put their skills to use in new ways to fight an enemy they had never encountered before: COVID-19. At the beginning of April, military engineers began designing a vehicle for testing members of the British public. These mobile testing unit (MTU) vehicles were then driven to car parks and other open spaces around the country to provide tests to key workers in the midst of the pandemic.

The team of engineers was given just one week to transform a standard Ford Transit van into a unit fit for delivering coronavirus tests. The process involved removing all the seating, deep-cleaning and stripping the panelling. It was essential that the van could store all the equipment separately, could be easily and frequently cleaned and was ready for deployment as soon as possible.

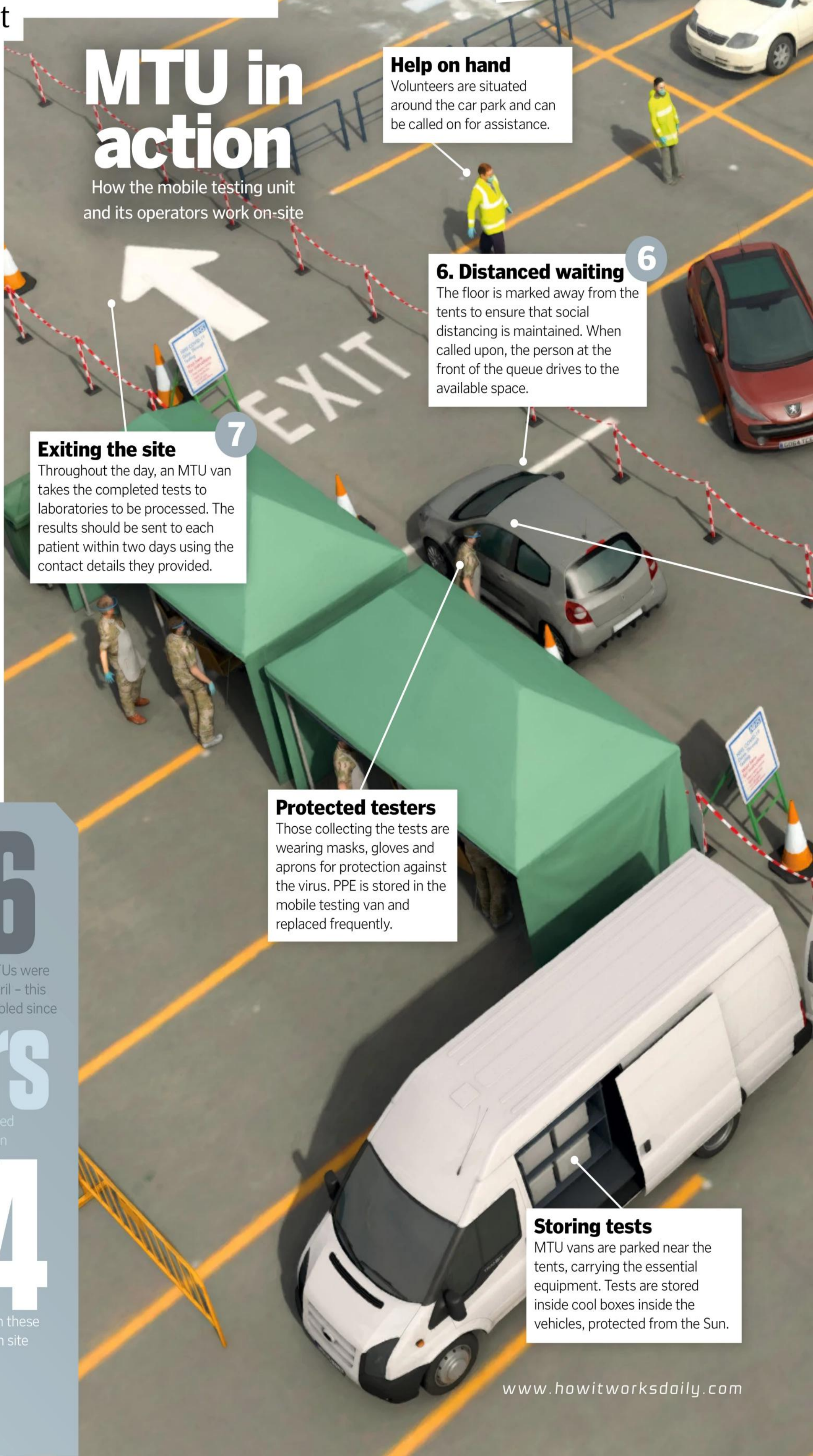
Now the army has trained civilians to conduct these tests. Still travelling the country, the MTU vans have collected over 700,000 tests. They have helped people make safer, more informed decisions on whether they need to isolate themselves from others to prevent transmission.

People being tested remain in their car throughout the process

© Getty

MTU in action

How the mobile testing unit and its operators work on-site



Help on hand
Volunteers are situated around the car park and can be called on for assistance.

6. Distanced waiting
The floor is marked away from the tents to ensure that social distancing is maintained. When called upon, the person at the front of the queue drives to the available space.

7 Exiting the site
Throughout the day, an MTU van takes the completed tests to laboratories to be processed. The results should be sent to each patient within two days using the contact details they provided.

Protected testers
Those collecting the tests are wearing masks, gloves and aprons for protection against the virus. PPE is stored in the mobile testing van and replaced frequently.

Storing tests
MTU vans are parked near the tents, carrying the essential equipment. Tests are stored inside cool boxes inside the vehicles, protected from the Sun.

87,200
The daily testing capacity of these units is met with their efficient drive-up system

96
Almost 100 MTUs were deployed in April – this number has doubled since

7 days
British Army engineers had limited time to design these vehicles

48 hours
The aim is for test results to be delivered within two days of a swab being taken

2,784
military personnel have helped out with these units, with at least 12 working at each site

© Ministry of Defence

1 Taking details
People's names and addresses are recorded upon arrival. If the individual wishes to take the test themselves they are sent to the first tent, but if they want someone to do it for them they are directed straight to the final tent.

2 Test explanation
Those being tested are given a test kit and an explanation of how to swab their nose and throat.

3 Park up
Those carrying out the test themselves park in an allocated space.

4 Orderly queue
Either with the completed test or waiting to be tested, cars wait in a line at the end of the site for a tent to be available.

5 Handover
At the second and final tent, people hand over their used kit, or are tested through their car window. These are then taken straight to the MTU.

What's in the van?

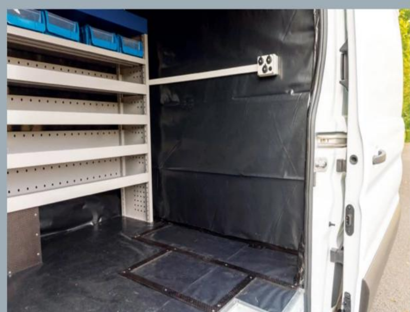
In the boot, away from the important testing kits, folded tents, tables, barriers and traffic cones are neatly stored. These are easily accessible in a separate area of the van so that the team can quickly get the parts they need, building the site in just 15 minutes and creating a sense of order for those arriving. A hand-washing unit has been installed at the back of many MTUs for the teams to use regularly while working around the unit.

In the middle of the van, shelves have been built to hold substantial weight. Panels divide the shelves to give each testing component a designated section, while used test kits ready for the laboratories are safely stored in electric cool boxes.

The floor has been replaced with easily cleanable and durable stainless steel. Initially all the materials used to build the MTUs had to be sourced within the engineers' camp, because lockdown had shut down most shops at the time.

© Ministry of Defence

The shelves inside keep tests and other equipment in place while the vehicle travels between sites



© Ministry of Defence

The inside of the van is lined with a vinyl wrap that can be frequently cleaned

Illustration © Adrian Mann

10 MILESTONES OF SPACEFLIGHT

HOW HAVE THESE MISSION FIRSTS TRANSFORMED OUR UNDERSTANDING OF SPACE?

Words by **Ailsa Harvey**

When SpaceX launched its Dragon capsule into orbit earlier this year, it became the first private spacecraft to carry humans to the International Space Station (ISS). Built for commercial travel, the successful flight served as a glimpse into the future of space tourism. But what other missions – both successful and disastrous – have provided us with the knowledge we have today? What achievements from the past have given us the confidence to send people and machines soaring above Earth?

The history of spaceflight spans a relatively short timeline, but in less than a century exploration beyond Earth has rapidly evolved. This is largely due to the competition between Cold War rivals, the Soviet Union and the US. While the Space Race encouraged speedy developments between the two competing sides, these came with dangerous acts and desperate decisions.

Without these risks, however, astronomers and engineers wouldn't be as knowledgeable as they are today. The universe has become a scientist's playground, and the further we explore, the more there is to uncover. These are just some of the brave individuals, ingenious journeys and technological marvels that have extended the limits of space exploration.

Sputnik 1 was only 58 centimetres in diameter, but weighed 83 kilograms

© Alamy

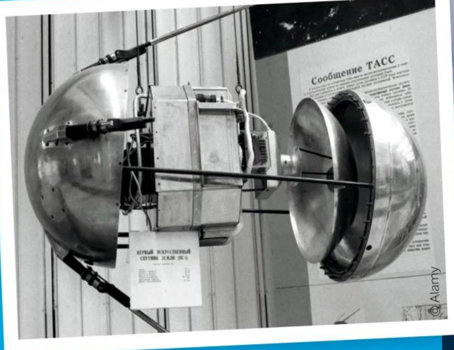
1957

Satellite success

SPUTNIK 1

01 Confidence comes with proof of possibility, and Sputnik 1 provided the first evidence that space was within our reach. When the Soviet Union launched an object the size of a basketball into Earth's orbit, it was set to become a significant moment in history. This satellite was the first human-made object to be successfully sent to space, and it marked the beginning of space exploration.

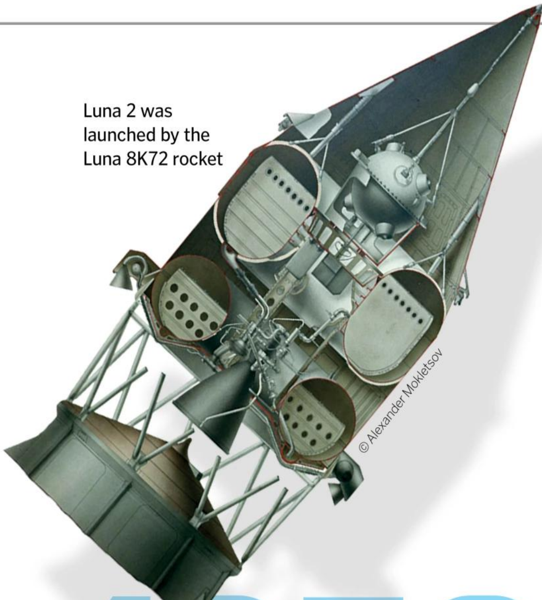
Monitoring Sputnik 1 as it travelled through space collecting data, the possibility of following it with more missions opened up. Its name means 'travelling companion' in Russian, though Sputnik was just a small silver sphere with four antennae attached to its body. By the time the legendary satellite burned up in 1958 as it re-entered Earth's atmosphere, it had spent three months patrolling space. In this time it completed 1,440 orbits of Earth and travelled 70 million kilometres. Not only did Sputnik 1 pave the way for spaceflight, by monitoring the object's drag and radio signals astronomers were able to glean valuable data about the upper atmosphere, such as its density.



Sputnik looks dated now, but was the peak of technological achievements in 1957

© Alamy

© Getty



Luna 2 was launched by the Luna 8K72 rocket

1959

Learning to land

LUNA 2

02

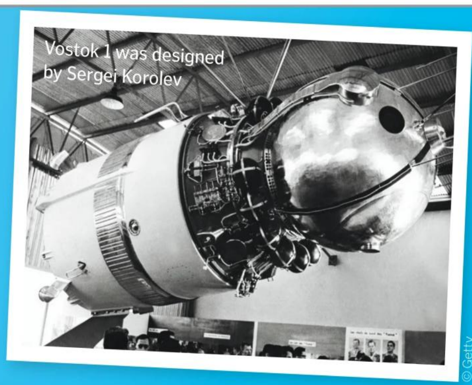
With no technology in place to slow spacecraft for landing, Luna 2 really did touch down with a bang. After a 36-hour journey across space, the spacecraft became the first to successfully reach the lunar surface. Not only was it first to the Moon, it was the first human-made object to land on any celestial body. Venturing into uncharted territory, Luna 2 concluded that the Moon had no significant magnetic field or radiation belt.

Since this milestone, humans have sent many more spacecraft and robots to view several other planets and moons. Engineering has advanced to make landing on these celestial bodies a much softer affair.

1961

Humans in space

VOSTOK 1



Vostok 1 was designed by Sergei Korolev

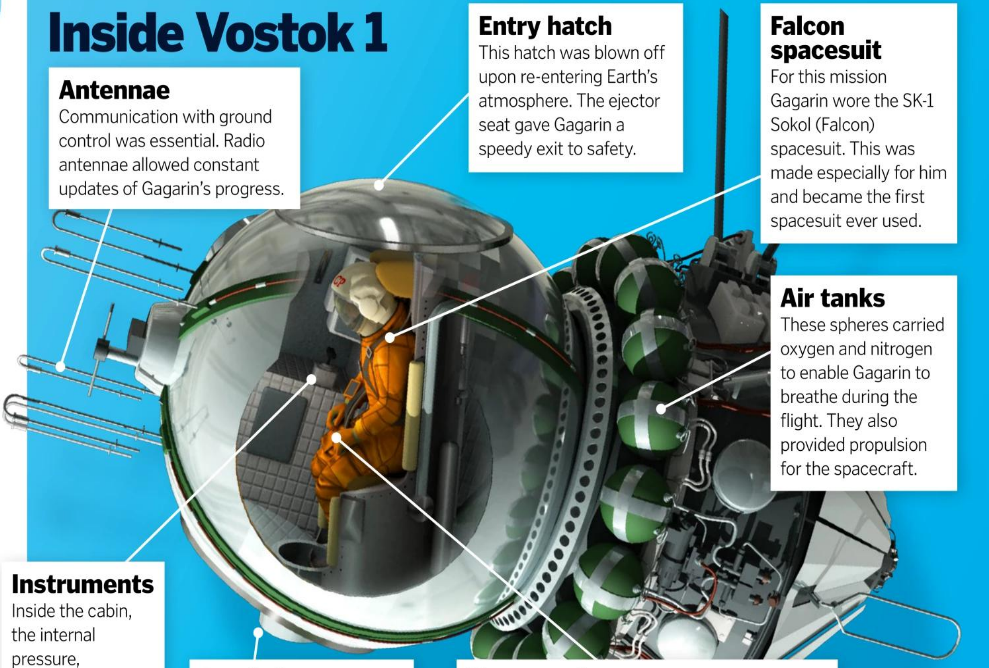
03

As scientists today explore the possibility of extraterrestrial human settlements, it's astonishing to think that before 1961, not a single person had even experienced spaceflight.

It was Russian cosmonaut Yuri Gagarin who took the first flight into orbit on 12 April 1961. Travelling in his spherical cabin called Vostok 1, Gagarin had spent years training as a pilot before this monumental moment. The launch and flight itself were a success, with his single orbit uneventful. However, after the 108-minute-long flight, it was on the return to Earth that Vostok 1 experienced trouble.

When the cables connecting its descent module and service module failed to separate from each other, the spacecraft began to jerk and shake uncontrollably as it approached Earth. Gagarin made the wise decision to eject before landing, but this choice meant that the trip couldn't be regarded as the first successful manned mission to space. Even without the manned landing, Yuri Gagarin is still considered to be the first human to go into space.

Inside Vostok 1



Antennae
Communication with ground control was essential. Radio antennae allowed constant updates of Gagarin's progress.

Entry hatch
This hatch was blown off upon re-entering Earth's atmosphere. The ejector seat gave Gagarin a speedy exit to safety.

Falcon spacesuit
For this mission Gagarin wore the SK-1 Sokol (Falcon) spacesuit. This was made especially for him and became the first spacesuit ever used.

Air tanks
These spheres carried oxygen and nitrogen to enable Gagarin to breathe during the flight. They also provided propulsion for the spacecraft.

Instruments
Inside the cabin, the internal pressure, temperature and orbital position above Earth was tracked and monitored.

Portholes
Gagarin had three portholes surrounding him. These small windows allowed him to view his outside surroundings from different angles.

No controls
Being the first manned mission, it was unknown how the human body would react to the low-gravity atmosphere. For this reason Gagarin was not given control over the spacecraft except in the case of an emergency.

1962

Exploring Venus

MARINER 2

04

For most of us, everything we have experienced has taken place on Earth. But in order to better understand our own planet, we need to learn about the others that surround us in the Solar System.

The first data collected from another planet came during the Mariner 2 mission when it flew by Venus on 14 December 1962 after a successful launch in August. After its predecessor, Mariner 1, was destroyed minutes after leaving the launchpad when its software failed, this second mission reached Venus and succeeded in analysing the planet's atmosphere, magnetic field, mass and charged particle environment. Thanks to this we know of Venus' hot surface temperatures, high surface pressures and thick cloud cover.

During its journey to and past the planet, further discoveries were made about the environment surrounding the Solar System's planets. Mariner 2 detected that there is a continuous solar wind as charged particles fly from the Sun in a giant stream.

Technicians attach solar panels used to power Mariner 2

Valentina Tereshkova was 26 years old when she went to space

© Alamy

1963

First woman in space

VOSTOK 6

05 When Valentina Tereshkova returned from her space trip, not only had she become the first woman to fly into orbit, but she had also spent more time there than all US astronauts that had flown before her.

At the time of her journey into space, solo space travel was deemed to be the most demanding feat, and Tereshkova showed this was one that women were equally capable of achieving. By the time the first American woman ventured in to space two decades later, only one other woman had matched Tereshkova's achievement. Following in her footsteps, 65 women have now flown to space.

1965

Spacewalking

VOSKHOD 2

06 A spacecraft acts as a shield to protect anyone inside from the harsh environment of space, incompatible with the human body. Having made it successfully out of Earth's atmosphere, why would anyone leave this safety bubble? On 18 March 1965, Alexei Leonov did just that as he completed the first-ever spacewalk.

Spending about 12 minutes suspended outside Voskhod 2, he showed that with the aid of a suit, humans could survive in open space. Leonov later described the experience as feeling "like a seagull with its wings outstretched, soaring high above the Earth".

© Getty

After the first spacewalk, Leonov struggled to re-enter the airlock as his suit had expanded so much

1981

The reusable spacecraft

COLUMBIA

Columbia was the first Space Shuttle to reach space

© NASA

07 Before NASA's first Space Shuttle launched on 12 April 1981, launch days for spacecraft only happened once. Upon their return the vehicles would be damaged or destroyed by the impact and the intense heat upon re-entry through Earth's atmosphere.

Improving the cost efficiency and reusability of spacecraft, the Space Shuttle Columbia undertook 28 missions and spent over 300 days in space. During its lifetime Columbia travelled over 200 million kilometres, reduced the costliness of space travel and opened up the possibility of commercial space travel.

1997

Rovers on Mars

PATHFINDER

08 Within our Solar System, the Red Planet is the second most habitable after Earth. With gravity similar enough to Earth's that humans could adapt to it, relatively high levels of sunlight and extractable water, it is no surprise that scientists are keen to investigate the possibility of colonising the planet.

Many of the discoveries on Mars were made by rovers. The first of these robots sent to the Red Planet was Sojourner, part of the Pathfinder mission. The aim of this mission was to deliver science instruments to Mars for research. The rover outlived its life expectancy 12 times over and has been followed by many other Mars exploration rovers from different countries.

These robots can patrol the surface, remotely controlled by humans. Taking remote-controlled vehicles to the extreme, the operators of these rovers can navigate Mars without leaving Earth. However, due to the vast distances involved, there is an average of 20 minutes delay from command to action. Thanks to Sojourner's success, the Mars Pathfinder mission obtained 2.3 billion bits of data, including nearly 20,000 images. Rovers have since discovered incredible finds, from mineral-rich rocks and signs of water to features detailing past events, like craters and ancient volcanoes.

This photograph of the Sojourner rover was taken shortly after landing on Mars

© NASA

© NASA

Sojourner's successors

Mars rovers have a variety of different mission objectives

SPIRIT
JAN 2004 - MAR 2010

Spirit found evidence of past water, geothermal activity, hot springs and volcanoes.

OPPORTUNITY
JAN 2004 - JUN 2018

Opportunity lasted 60 times longer than planned, producing over 217,000 images of Mars.

CURIOSITY
AUG 2012 – PRESENT

Just seven months after landing, Curiosity discovered that Mars was once warmer, wetter and more habitable.

PERSEVERANCE
2021

This NASA rover will head for the planet's Jezero Crater, once home to a lake. Scientists hope to find signs of ancient life there.

TIANWEN 1
2021

China's first Mars rover is on its way to Mars. It will observe the underground structure of the planet and its magnetic field.

ROSALIND FRANKLIN ROVER
2023

The first of its kind to carry out in depth analysis of Mars' surface as it searches for past and present signs of life.

1998

Building the ISS

ZARYA

09

Following the emergence of reusable spacecraft, creating a base camp for humans in space became a possibility. In November 1998, the first piece of the International Space Station (ISS) was launched into space. Since then the contributions of 15 nations around the world have built a mammoth space vessel. Acting as a stable location for space explorers to call home, the ISS also contains research laboratories for space experiments.

After the launch of its core module, Zarya, the ISS took ten years and roughly 30 missions to assemble. The finished station has the volume of a six-bedroom house and the surface area of a football field. Thanks to each assembly mission, today it is possible for there to be a continuous human presence in space as we further explore untouched grounds and new possibilities.

© NASA

Crew members spend Christmas morning at the International Space Station

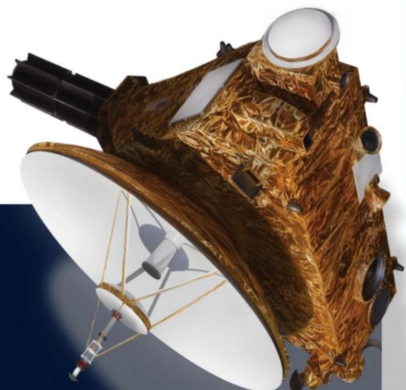
© Getty

The International Space Station uses electrical power from 262,400 solar cells

2015

Pluto flyby

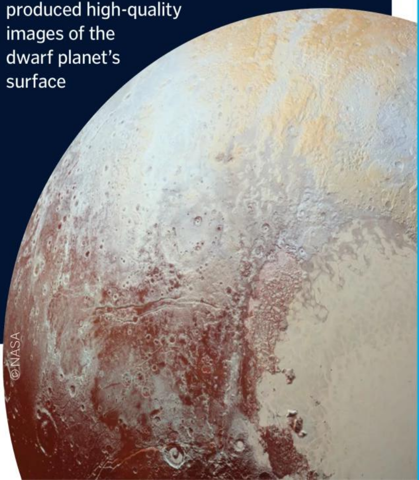
NEW HORIZONS



10

Taking off from Earth in 2006, this space probe's main mission was to carry out a flyby study of Pluto and return data. As it flew over the surface of the dwarf planet, it became the first spacecraft to image its surface in great detail. New Horizons showed us what the celestial bodies at the very edge of our Solar System are like. The probe began relaying data about Pluto and one of its moons, Charon, five months before the closest encounter. Ten weeks before the flyby it was already producing images of better quality than the Hubble Space Telescope.

Among the mission's top findings was a much colder atmosphere on Pluto than anticipated. The dwarf planet is home to the largest known glacier in the Solar System and has frozen mountains protruding from its surface. Having conquered Pluto, New Horizons didn't stop there. On 1 January 2019 the probe took close-up images of space rock 486958 Arrokoth, the most distant object ever explored by a spacecraft.

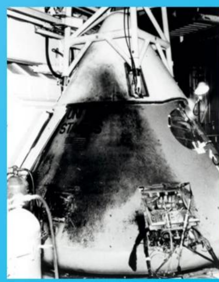


The Pluto flyby produced high-quality images of the dwarf planet's surface

© NASA

5 IMPORTANT TRAGEDIES

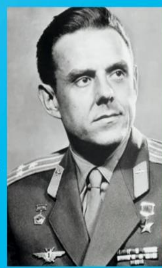
APOLLO 1 FIRE 1967



© NASA

NASA's first manned Apollo spaceflight was set to be a practice launch to space for the first Moon landing, but while still on the ground the three astronauts inside were engulfed in a fatal fire. Flaws including flammable materials in the spacecraft and a difficult emergency escape were redesigned to create safer environments for future Apollo flights.

SOYUZ 1 EXPERIMENT 1967



© Getty

Sadly demonstrating the dangers of spaceflight under political pressure, a Soviet craft carried cosmonaut Vladimir Komarov to his death. 203 technical issues were reported before liftoff, but the flight went ahead anyway in an attempt to overtake the US in the Space Race. When Komarov's parachute failed to open, he became the first person to die during a mission.

CHALLENGER'S FINAL FLIGHT 1986

© NASA

The Challenger Space Shuttle had successfully become the second to fly to space, but on its tenth mission, disaster struck. 73 seconds after liftoff, the shuttle broke apart due to cold weather impacting the rocket's rubber seals. These sealed the fuel segments inside the rocket, but in the extreme cold the rubber seals became too stiff, resulting in a fuel leak. The resulting investigation recommended that NASA install and improve safety features on the shuttles as well as its management of future missions.

COLUMBIA 2003

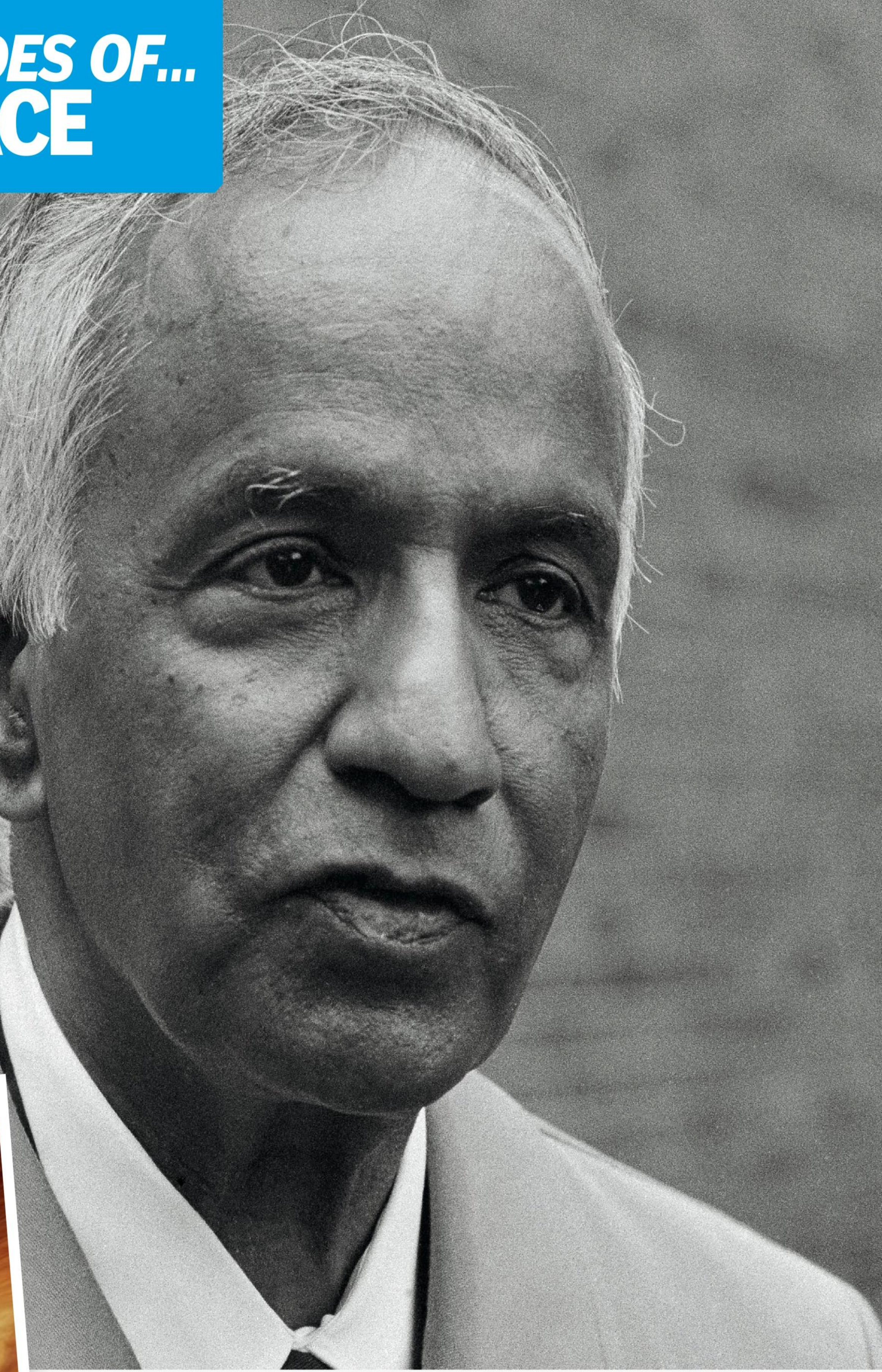
© NASA

When Space Shuttle Columbia re-entered Earth's atmosphere after its 28th mission it was torn apart, taking the lives of its seven crew members. In the following two years, NASA's investigation found that a hole on the left wing allowed atmospheric gases to enter the shuttle. The disaster showed how a small area of damage could result in complete devastation.

FALCON 9 2015

© NASA

Aerospace company SpaceX had a mishap with one of its launching rockets in 2015 when a steel strut which was holding helium snapped, triggering an explosion. The private company became more wary of who it used as suppliers and closely monitored the condition of all small parts.



Chandrasekhar debated the last moments of a star's life and proposed the birth of something new after its demise

©Getty

Chandrasekhar's work on star death paved the way for understanding the creation of black holes

© NASA/JPL-Caltech

A life's work

A star of astrophysics

1910
Chandrasekhar is born in modern-day Pakistan and begins his education at home before venturing off to college.

1930
Chandrasekhar arrives in England to study for his doctoral degree at Cambridge University.

1933
Following the completion of his PhD, he was awarded a Prize Fellowship at Trinity College.

1937
Travelling across the pond, Chandrasekhar joined the University of Chicago, where he would remain for the rest of his career.

Subrahmanyan Chandrasekhar

Meet the astrophysicist who redefined the meaning of a 'star'

Born in 1910 in Lahore in the Punjab province of British India, now Pakistan, Subrahmanyan Chandrasekhar was one of ten children born to father Chandrasekhara Subrahmanya Ayyar, an Indian government auditor, and mother Sita Balakrishnan.

Beginning his education at home, Chandrasekhar went on to attend the Hindu High School in Triplicane before journeying on to Presidency College in Madras, where he completed a bachelor's degree in physics in 1930. Recognising his aptitude for the subject, a special government scholarship was awarded to Chandrasekhar to travel to England's prestigious Cambridge University and continue his studies for a further three years to obtain a PhD. Chandrasekhar was set to work with well-known British physicist and astronomer Ralph Howard Fowler.

It was his journey to England that would bear the fruits of his academic prowess. With only a handheld calculator, Chandrasekhar began to calculate the statistical mechanics of the degenerate electron gas in white dwarf stars to pass the time while shipbound. His calculations would become the foundations for a theory that all stars, in burning up the last of their available fuel, became planet-sized remains called white dwarfs. This was what his mentor Fowler had also postulated, but where Fowler's theory had closed the book on the white dwarf's story, Chandrasekhar wanted to write another chapter. His view was that the forces that hold a white dwarf together could only do so up to a certain point. Chandrasekhar suggested that if a white dwarf had enough mass, it could no longer resist the force of gravity and the star would collapse, writing that "one is left speculating on other possibilities".

Chandrasekhar's new way to view the life span of stars caused a stir in the scientific community, rivalling the theories of a respected scientist and friend of his, Sir Arthur Eddington. Like Fowler, Eddington believed that in the last stage of a star's life it would become a white dwarf. Eddington went as far as publicly calling out Chandrasekhar's work as false at a Paris conference. If Chandrasekhar's theoretical work was proven true, it would undermine Eddington's theories and redefine our understanding of the last phases of a star's life.

In the years that followed Chandrasekhar published countless papers in the field of physics, unravelling more secrets of space with each one. His work on dense neutron stars and black holes has become a central part of modern-day astrophysics. However, he went relatively unrecognised for his pioneering work on that long ship journey. It would be decades before Chandrasekhar received recognition for his work, when in 1983 he received the Nobel Prize in Physics, shared with William Fowler, for his groundbreaking work.

THE BIG IDEA

Redefining the limits of stars

White dwarfs are incredibly dense objects inhabiting space. To prevent the atoms that make up a white dwarf from being ripped apart by the force of gravity, something called electron degeneracy pressure holds the star together. However, as a white dwarf uses the last of its fuel it becomes increasingly dense.

Chandrasekhar determined that if a white dwarf reaches 1.4 times the mass of our Sun, the electron degeneracy pressure can no longer fight against gravity, resulting in a spectacular supernova. After an impressive outburst of energy, what remains is a neutron star. We now know that if a star's mass is large enough at this stage, the enormous output of energy and mass could result in it collapsing into a black hole. This breaking point during a star's death became known as the Chandrasekhar limit.

As a star collapses under its own weight, protons and electrons combine to form neutrons, hence the name 'neutron star'

FIVE THINGS TO KNOW ABOUT...
SUBRAHMANYAN CHANDRASEKHAR

1 His uncle also won a Nobel Prize
Nobel Prize wins ran in Chandrasekhar's family: his uncle, Sir C.V. Raman, won the Nobel Prize in Physics in 1930 for producing groundbreaking work in the field of light scattering.

2 He was an editor
Not only did he have his work published in many academic journals, Chandrasekhar was the editor of *The Astrophysics Journal* from 1952 to 1971.

3 A telescope is named after him
Launched in 1999, the Chandra X-ray Observatory orbits Earth hunting for black holes, nebulae and supernovae. This telescope can study particles up to the last millisecond before they fall into a black hole.

4 He was a decorated academic
He received 20 honorary degrees and was awarded several medals, such as the Gold Medal of the Royal Astronomical Society and Henry Draper Medal of the National Academy of Sciences.

5 Invited to join the Manhattan project
Chandrasekhar was asked to assist as the explosive force of the bomb was likened by some to an exploding star. However, due to a delay in his FBI clearance he was unable to help.

1939
Chandrasekhar publishes *An Introduction to the Study of Stellar Structure*, offering new ideas on the fate of dying stars.

1983
Chandrasekhar publishes *The Mathematical Theory of Black Holes* through Oxford University Press.

1983
Along with William Fowler, Chandrasekhar wins the Nobel Prize in Physics for the work he started over 50 years prior.

1995
On 21 August Chandrasekhar dies at the University of Chicago Hospital after a heart attack.

Chandrasekhar married his wife Lalitha in 1936; here she stands next to the Chandra X-ray Observatory
© NASA

Taken in 2013, this image of Comet Lovejoy was snapped when it was almost 60 million kilometres from Earth

© Wally Pacholka

What are comets made of?

What are these blazingly bright balls in the sky and where do they come from?

Words by **Scott Dutfield**

They're known as cosmic snowballs, but rather than compacted snowflakes, comets are frozen balls of gases, rock, ice and dust in huge orbits around the Sun. You wouldn't be able to hold one in your hands either, as they can be the size of a small town. When they approach the Sun and heat up, they release massive tails of gas and dust that can stretch for millions of kilometres behind them.

Comets have been whizzing around our Solar System since its birth 4.6 billion years ago, and have likely remained unchanged since. Some originate from the swirling ring of gas and rock that surrounds our Solar System, known as the Kuiper Belt. As the belt rotates in orbit, some comets become dislodged and hurtle towards the Sun. However, not all of these meet a fiery doom.

On their gravitational orbit around the centre of our Solar System, some comets collide with planets. One planet that's taken a particular beating from these volatile balls of ice is Jupiter. Back in 1994 pieces of Comet Shoemaker-Levy 9 crashed into the gas giant, creating huge scars in its atmosphere.

There is also a spherical globe that encapsulates our Solar System called the Oort Cloud, thought to be another home to comets. The time it takes for a comet to orbit the Sun can be relative to the location it entered orbit. The closer the comet is to the Sun when it enters orbit, the less time is taken to complete a single orbit when compared to the comets that travel from the far-reaching Oort Cloud that surrounds our Solar System.

The Oort Cloud is so far away from the Sun that a specific measure of distance is used to indicate its location, called an astronomical unit (AU). A single AU equals the distance from the Sun to Earth. The innermost point of the Oort Cloud is between 2,000 and 5,000 AU away, which is a lot when you consider Pluto is 'just' 30 AU from Earth.

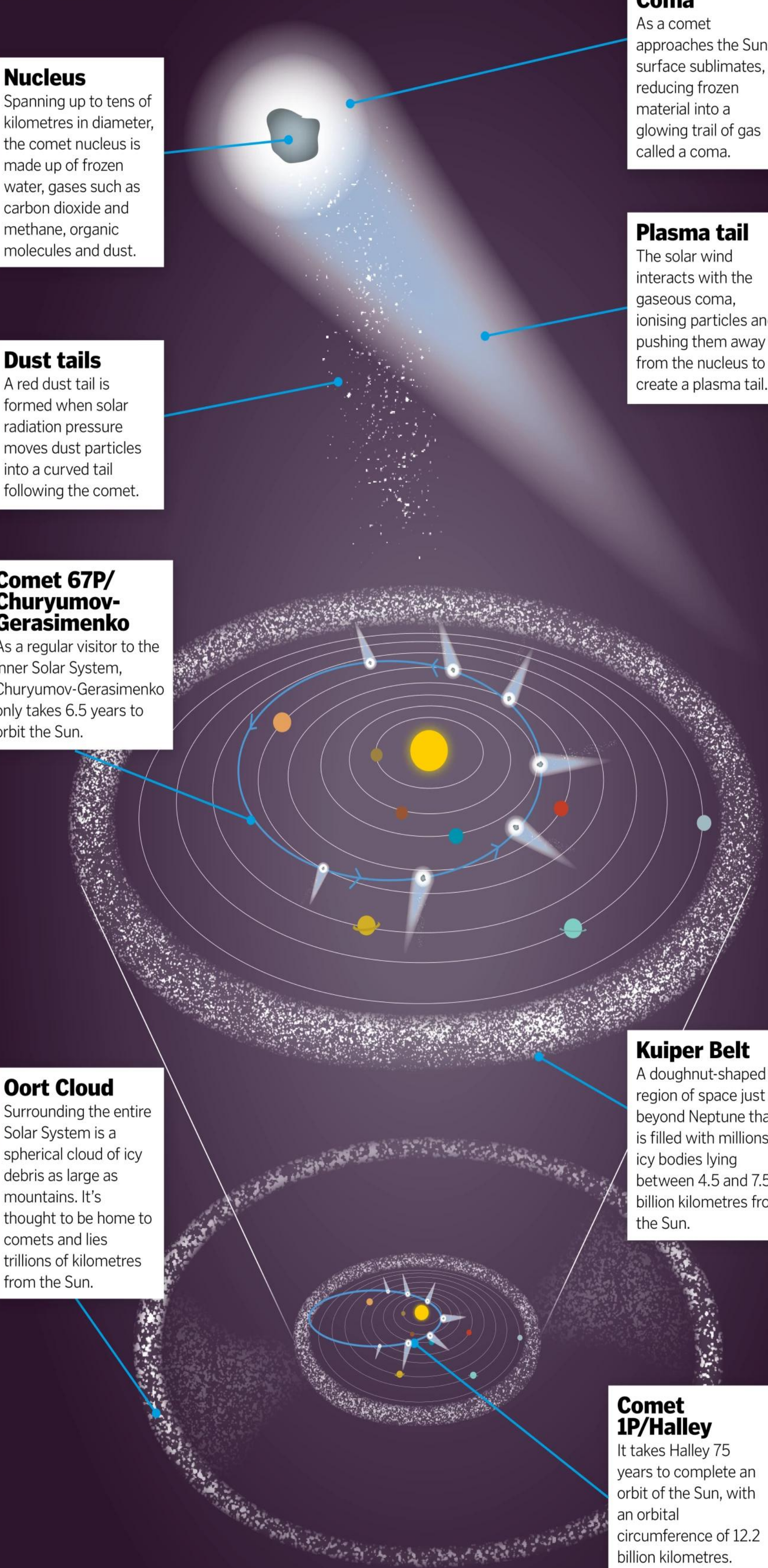
"When they approach the Sun and heat up, they release massive tails of gas and dust"

© NASA/MSFC/Jacobs Technology/ESSSA/Aaron Kingery

Comet Hale-Bopp was spotted travelling across the sky of Indian Cove, California, in 1997

Anatomy of a cosmic snowball

Take a close-up look into what makes a comet



Nucleus
Spanning up to tens of kilometres in diameter, the comet nucleus is made up of frozen water, gases such as carbon dioxide and methane, organic molecules and dust.

Coma
As a comet approaches the Sun its surface sublimates, reducing frozen material into a glowing trail of gas called a coma.

Plasma tail
The solar wind interacts with the gaseous coma, ionising particles and pushing them away from the nucleus to create a plasma tail.

Dust tails
A red dust tail is formed when solar radiation pressure moves dust particles into a curved tail following the comet.

Comet 67P/ Churyumov-Gerasimenko
As a regular visitor to the inner Solar System, Churyumov-Gerasimenko only takes 6.5 years to orbit the Sun.

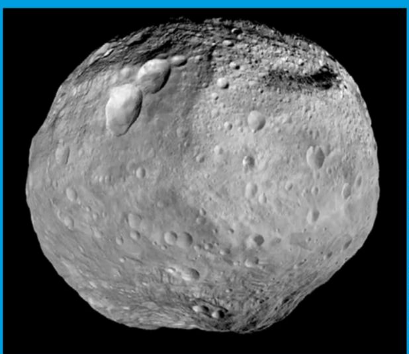
Kuiper Belt
A doughnut-shaped region of space just beyond Neptune that is filled with millions of icy bodies lying between 4.5 and 7.5 billion kilometres from the Sun.

Oort Cloud
Surrounding the entire Solar System is a spherical cloud of icy debris as large as mountains. It's thought to be home to comets and lies trillions of kilometres from the Sun.

Comet 1P/Halley
It takes Halley 75 years to complete an orbit of the Sun, with an orbital circumference of 12.2 billion kilometres.

Classifying space rocks

What's the difference between an asteroid, comet, meteor and meteorite? They all sound similar but they do have some distinct differences. As we know, comets are frozen bodies orbiting the Sun whose vaporising ice forms their tails, whereas asteroids are made up of metal and rock and are mostly found in a region of space between Mars and Jupiter called the asteroid belt. Both comets and asteroids were formed during the formation of our Solar System around 4.6 million years ago. Asteroids smaller than the size of a pebble are called meteoroids. Meteors and meteorites are cosmic crumbs from broken comets, or chunks thrown off a planet's surface, that hit another planet, like Earth. They can range in size from just a grain of sand to extinction-event space rocks kilometres wide, like the one that wiped out the dinosaurs about 66 million years ago. If these are vaporised at high speeds in the atmosphere they're referred to as meteors. If they survive the intense heat of atmospheric entry and hit the ground, they're called meteorites.



Asteroids are the rocky leftovers of the formation of the Solar System. Vesta is the largest asteroid known, with a diameter of about 530 kilometres

Antarctica's many meteorites

Why this frozen wasteland is a hotspot for space rocks

Words by **Scott Dutfield**

What can Earth's frozen south tell us about worlds beyond our own? Scattered across the icy blanket of Antarctica are countless nuggets of cosmic data in the form of meteorites. They don't have a particular affinity for landing in Antarctica and can be found around the world, but the ease of looking for them on this snow-laden continent comes simply because they're easy to spot.

As dark lumps of rock, meteorites contrast the white backdrop, allowing researchers to find them with relative ease. Back in 2016 a two-month expedition yielded nearly 570 meteorite samples for research. The purpose of collecting these space rocks is to better understand our Solar System. Often originating from orbiting comets, asteroids and other planets, meteorites are jam-packed with information about how the Solar System formed and may contains signs of potential life on other planets.

For example, meteorites from some of the earliest asteroids in our Solar System's existence, called carbonaceous chondrites, are filled with amino acids, which are the building blocks of life as we know it. It's believed that when the molecules found in these rocks are heated they could form primitive cells, opening our eyes to our planet's evolution.

The Johnson Space Center and the Antarctic Search for Meteorites (ANSMET) are some of the leading collectors of Antarctic meteorites. Since 1976 ANSMET has gathered more than 22,000 meteorites to better understand how Earth and other planets formed in our Solar System.


A meteorite found on a blue ice field in the Miller Range of Antarctica

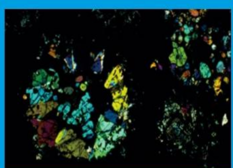

By the time these meteorites hit the surface they have formed a black fusion crust, created by the intense heat from air friction as they enter Earth's atmosphere

Types of meteorites

Iron meteorites

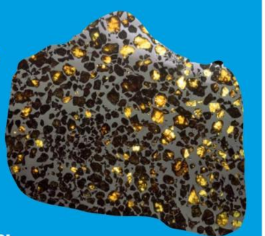
Typically iron meteorites contain 90 to 95 per cent iron. Two alloys are studied in these types of meteorites: kamacite and taenite. They form a linear arrangement called a Widmanstätten pattern, which is exposed when etched with acid.

Stony meteorites



Most stony meteorites have fallen to Earth from the asteroid belt between Mars and Jupiter, but a few may have come from Mars and the Moon. Some of these stony meteorites contain 'chondrules', small grains that originated in the solar nebula and predate the formation of Earth.

Iron-stone meteorites

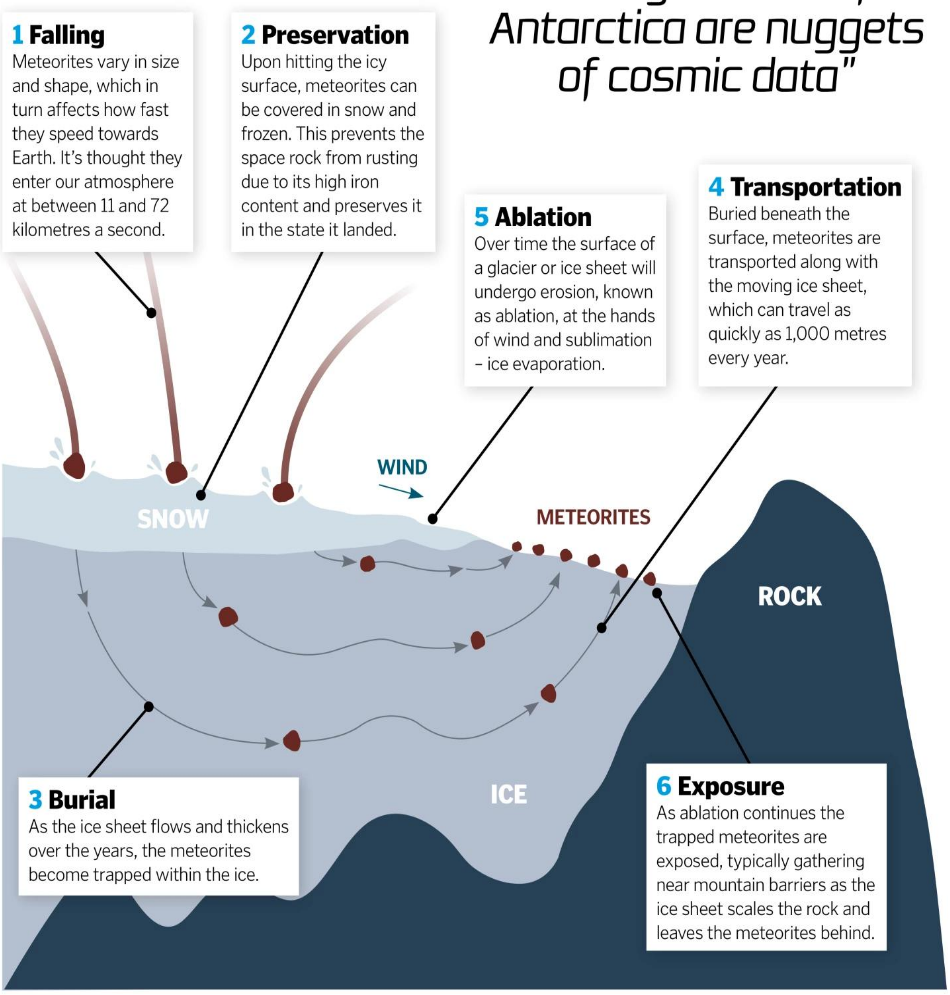


These account for just two per cent of all collected meteorites. They're divided into two subtypes: pallasites and mesosiderites. Pallasites contain translucent olivine crystals, whereas mesosiderites are mainly composed of igneous rock fragments.

From outer space

Where to find space rocks and how they move through the Antarctic ice

"Scattered across the icy blanket of Antarctica are nuggets of cosmic data"



WIN! A TELESCOPE

The Meade Polaris 130EQ comes with three eyepieces, slow-motion controls and is great for viewing the Moon, the planets and bright deep-sky objects

WORTH £220!

For your chance to win, answer the following question:

Which of the following dinosaurs had three horns?

a) **Triceratops** b) **T. rex**

c) **Stegosaurus**

Enter online at

howitworksdaily.com

and one lucky winner will win!

Terms and Conditions: Competition closes at 00:00 BST on 22 October 2020. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **futuretcs.com**. Entries must be received by 00:00 BST on 22/10/2020. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received, and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

BRAIN DUMP

Because enquiring minds need to know...

DID YOU KNOW?

Technically the UK's Houses of Parliament is owned by the Queen

What will happen to our Solar System after the Sun explodes?

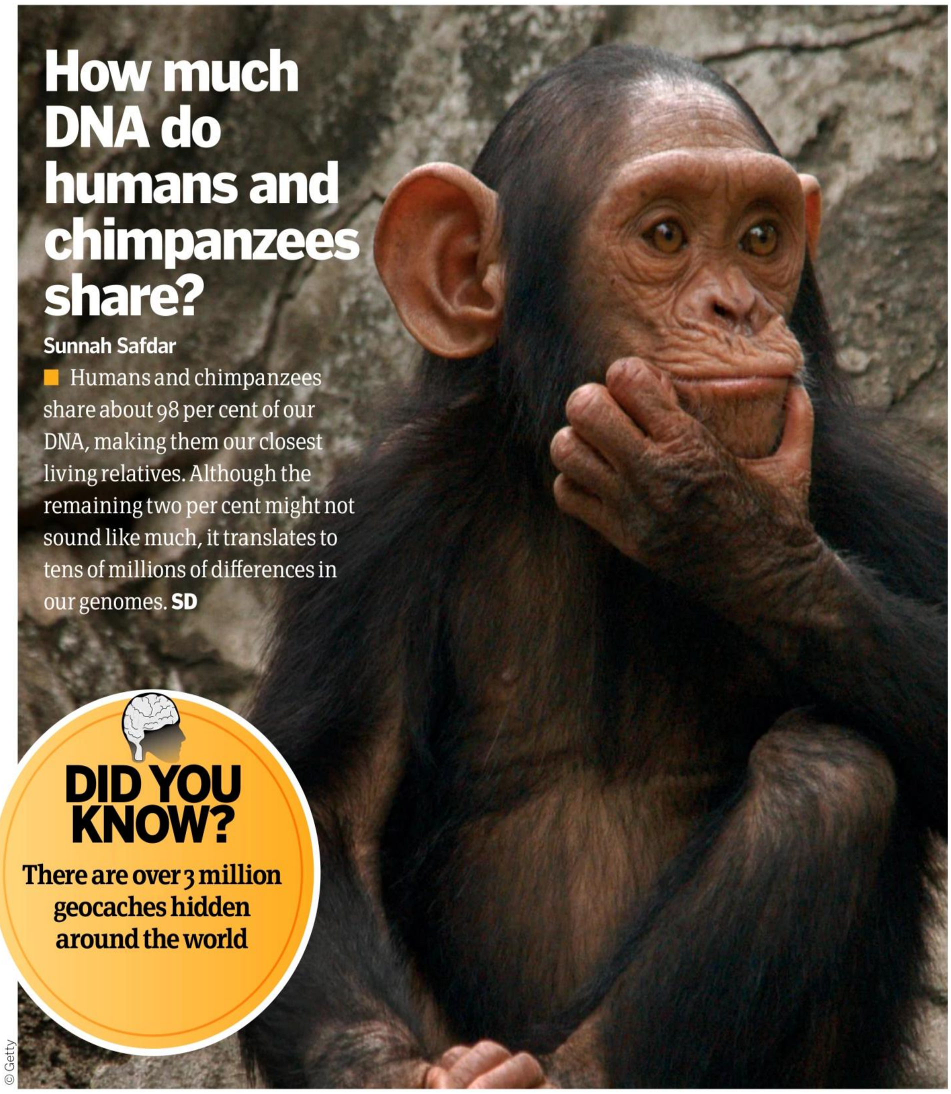
Arya Knowles

The Sun won't explode when it eventually dies – that's not the fate of the G-class yellow dwarf star at the centre of our Solar System. Between 5 and 7 billion years from now, the Sun will use up all its nuclear fuel and will swell to become a red giant star. It will engulf Mercury and Venus and push Earth outwards before sloughing its outer layers of hot gas and dust to form a planetary nebula with a small white dwarf – a stellar remnant – at its centre. Life on Earth will be gone long before that happens though, as the Sun will become hot enough to boil our oceans dry around 1.2 billion years from now. **BB**

The Sun will eventually expand to fill up most of the inner Solar System beyond Earth's current orbit and will shine 3,000-times brighter

WANT ANSWERS? Send your questions to...

How It Works magazine | @HowItWorksmag | @howitworks@futurenet.com



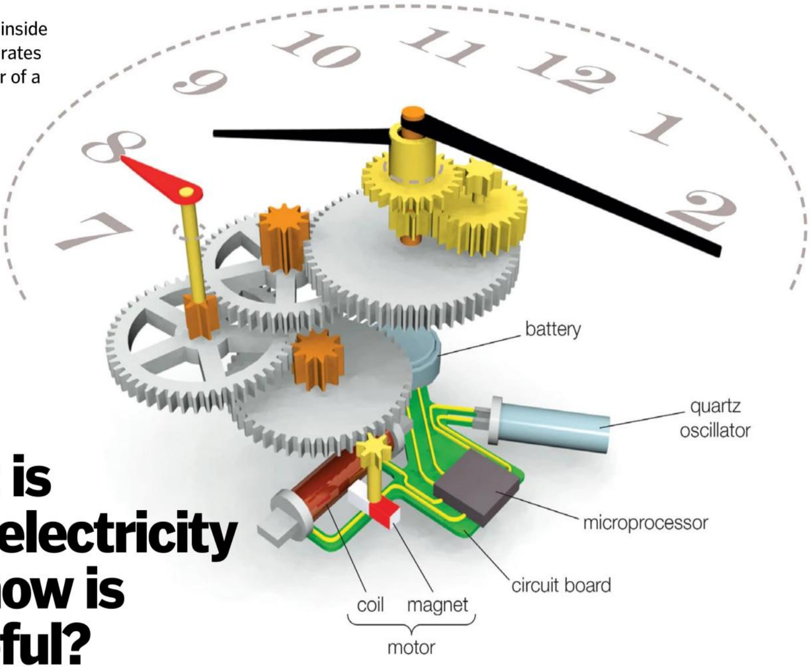
How much DNA do humans and chimpanzees share?

Sunnah Safdar

Humans and chimpanzees share about 98 per cent of our DNA, making them our closest living relatives. Although the remaining two per cent might not sound like much, it translates to tens of millions of differences in our genomes. **SD**

DID YOU KNOW?

There are over 3 million geocaches hidden around the world



A quartz crystal inside the oscillator vibrates to turn the motor of a quartz clock

What is piezoelectricity and how is it useful?

Archie Swain

Piezoelectricity is electricity created by squeezing crystals. The mechanical stress exerted on these crystals creates a voltage across its sides. Similar to a battery – with a positive end and a negative end – they can be connected to form a circuit. Scientifically a crystal is any solid with its atoms neatly arranged, such as quartz and iron.

This electricity generation is useful for a variety of situations where movement needs to be converted into electrical signals. Examples include microphones, where piezoelectricity is created from the sound energy, and quartz watches, which use the reverse process of converting electrical energy from the battery into mechanical energy to move the hour, minute and second hands. **AH**

Why was the Segway invented?

Luna Daly

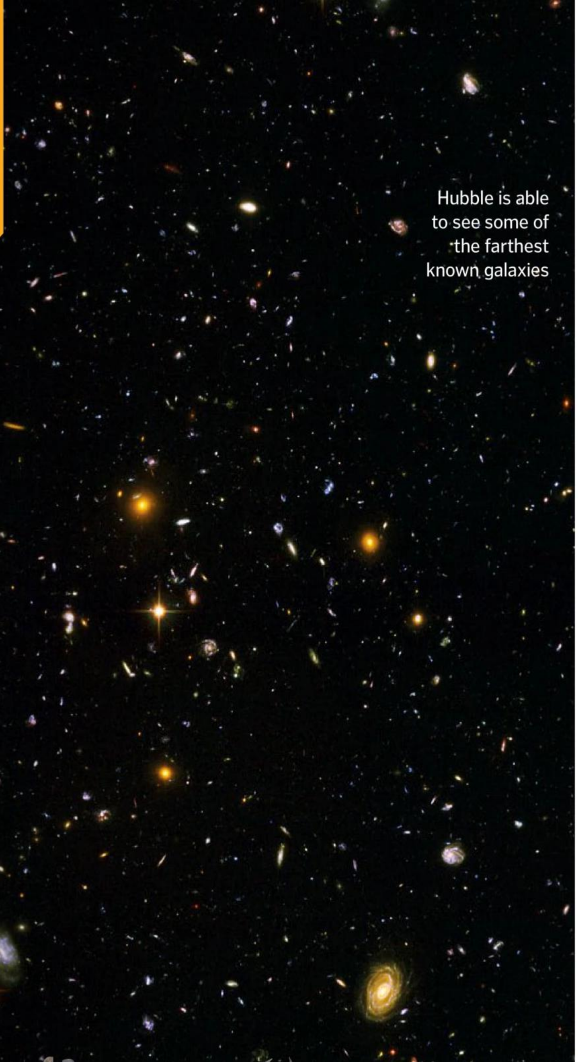
Segways can be a fun way to travel. The Segway was invented by Dean Kamen as a way to revolutionise how people traverse busy streets, first becoming available to the public in 2002. Many cities around the world have Segways that you can rent out to explore with ease. **NR**

Why do we have parliament? Why not just a king or queen?

Aisha Humzah

The origins of British parliament can be traced back a thousand years to when the monarchs of England would seek advice and support from a council before passing laws. Over centuries the power to legislate has shifted to this council, up until 1707, when the English and Scottish parliaments merged. Since then British monarchs have been more of a figurehead, approving some laws but playing a much more diminished role in the politics of the country. **BB**

BRAIN DUMP

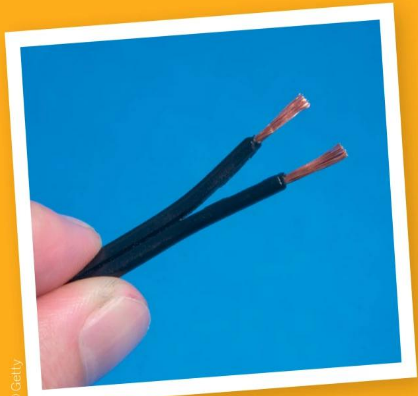


Hubble is able to see some of the farthest known galaxies

How did the universe's first matter form?

Mark Myerson

The universe's first matter formed in the aftermath of the Big Bang as the universe started to cool, starting with fundamental particles like quarks. One ten-thousandth of a second after the Big Bang, protons and neutrons formed – though physicists still aren't sure how this happened – and began to form the first atomic nuclei, hydrogen and helium. These eventually attracted electrons, making complete atoms. Over millions of years gravity pulled clumps of these atoms together, forming the first clouds of gas that would become the first galaxies in the universe. **NR**



Does electricity weigh anything?

Ronald Hammond

It weighs nothing, because to weigh something an object needs mass. Electricity is created when charged particles move along a wire, like the electrons that have a negative charge and move along the copper electric wires in your home. These subatomic particles have a tiny bit of mass – so little that scientists have to crunch numbers to calculate their weight – but because they exist in the wire whether or not a current is applied, the wire's mass doesn't change when electricity flows through it. **BB**

Geocache containers can range from micro capsules fitting a scroll of paper to larger boxes

What is geocaching?

Iram Safdar

Geocaching is a real-world outdoor treasure-hunting game using GPS-enabled devices, including smartphones. Participants use the device to navigate to a specific set of GPS coordinates and attempt to find the geocache. This is a container which is hidden at that location. The participants must sign the logbook and return the geocache to allow the next lot of hunters to track it down.

To keep track of those you've found, there is an app available to log them digitally. The main reason people geocache is to explore interesting locations while gaining a sense of achievement. Sometimes these containers also include 'treasure', with a variety of objects that people have added into the geocache or swapped out. **AH**

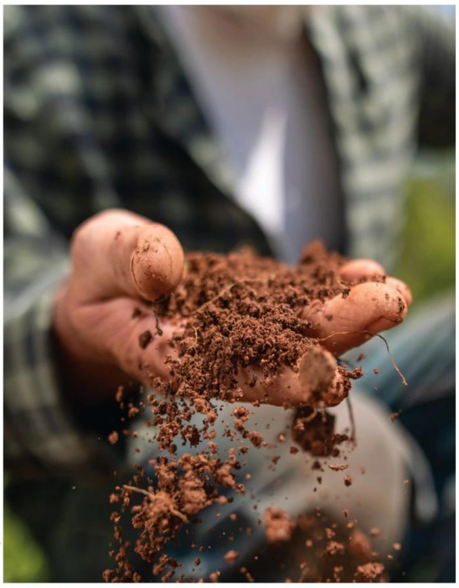
What is snot made of, and do other animals produce it?

Stephen Conn

Snot is made up of proteins called mucins, which are coated in sugars to adsorb water to become sticky. Antibodies and lysozymes are also present to activate the immune system and to break down bacteria. We are not the only species to boast boogers; many animals have snot to trap potential infectious microbes. Gorillas are often seen picking at their nostrils and blowing their noses. Mother bonobos also clear out the snot from their congested children. **SD**

DID YOU KNOW? Of the 43,000 species of spider, less than 30 can kill you

Without the use of fingers to pick at their nostrils, giraffes lick the snot out of their noses



© Getty

What is soil made of?

Craig Burr

Soil is made of a combination of natural materials. These include small rock particles, decaying plants and animals, water and air. Its different properties come from the different volumes of each component. Sandy soil contains larger particles with big air gaps, while clay soil has the opposite. Peat doesn't contain any rock particles at all, but is very rich in plant material. **AH**

© Getty

How do rechargeable batteries work?

Alex Wheeler

In all batteries an electrochemical reaction involving a cathode – the negatively charged electrode – an anode – the positively charged electrode – and an electrolyte, which serves as a catalyst to promote the movement of ions between the two, creates a current. In rechargeable batteries this can be reversed when electricity from another source is applied to a secondary cell, creating a positive to negative electron flow that restores charge. Many different combinations of chemicals are used in rechargeable batteries, including lithium. **NR**

Rechargeable batteries are better for the environment as they're reusable

DID YOU KNOW?

The first rechargeable battery was invented in 1859 by French physicist Gaston Planté

Why do people get scared of spiders?

Alex Roz

There are many reasons why someone might have a fear of spiders, which is known as arachnophobia. It can be explained by human evolution: early humans that were able to spot and recognise potentially dangerous animals such as spiders were more likely to survive than those that didn't. Those that weren't fearful of these animals may have died as a result, meaning that arachnophobia may have been passed on to subsequent generations and ingrained in our DNA over millennia. A traumatic event involving a spider as a child can instil a phobia of spiders, or a phobia may occur as a response to the unsettling unpredictability of a spider's skittering steps. **SD**

Not all spiders look scary; this jumping spider is adorable

© Getty

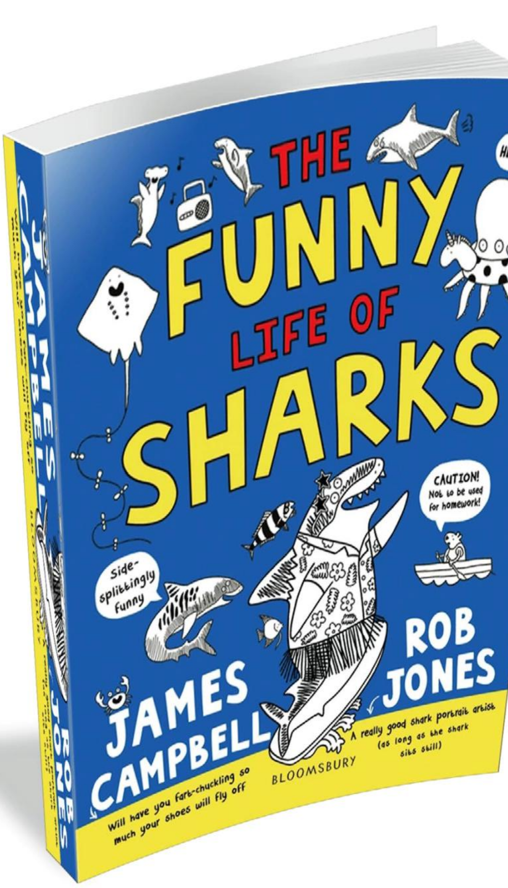
BOOK REVIEWS

The latest releases for curious minds

The Funny Life of Sharks

A silly underwater saga

- Author: **James Campbell and Rob Jones**
- Publisher: **Bloomsbury Children's Books**
- Price: **£6.99 (approx. $8.98)**
- Release: **Out now**



If you can laugh at the object of your fear, then that takes away at least some of its power to frighten you. It seems that this is one of the primary objectives that author James Campbell set out with when he wrote *The Funny Life of Sharks*. His message in this children's book is that we – as humans – have nothing to fear from sharks. Six people at most die from shark attacks every year – we're just not on their menu – whereas around 274,000 sharks are killed and eaten by people every day.

He writes unconventionally, sandwiching facts between jokes and small anecdotes that include his own observations of sharks in pop culture. This includes a story about Chinese basketballer Yao Ming, who played for the Shanghai Sharks and commissioned a TV advert that showed him pushing away a bowl of shark fin soup in disgust after learning about 'finning' in Asian fishing. There's a short chapter on this barbaric practice, which Campbell prefaces with a warning that it's disturbing and that readers might want to "skip it and find something funny" if they don't want to read about it.

In stating the case for sharks, Campbell uses land mammals whose own plight or importance is analogous to that of sharks', like the Cairngorm hares in the Scottish Highlands or the wolves of Yellowstone National Park. One is critically endangered and the other is an apex predator that plays a critical role in maintaining the health of its environment. Just because we very seldom see sharks, they have a dead-eyed stare and a terrifying mouth of sharp teeth, it doesn't make any shark less valuable than the warm-blooded, furry species we gravitate towards.

We – as humans – have nothing to fear from sharks

On the lighter side, Campbell talks at relative length about different types of sharks – especially the strange ones like the Australian Wobbegong. And there's plenty of suitably childish humour peppered throughout, accompanied by Rob Jones' illustrations, who has a style reminiscent of *Purple Ronnie* but without the stick men and fart gags. *The Funny Life of Sharks* is occasionally serious, but mostly it's a fun and funny book that will teach you a thing or two – even if you are old enough to have watched *Jaws* back in the 1970s.

★★★★☆

Look Up

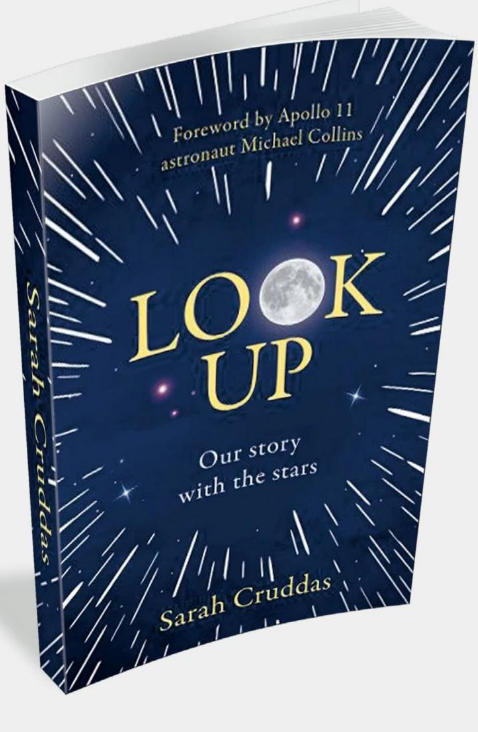
Our story with the stars

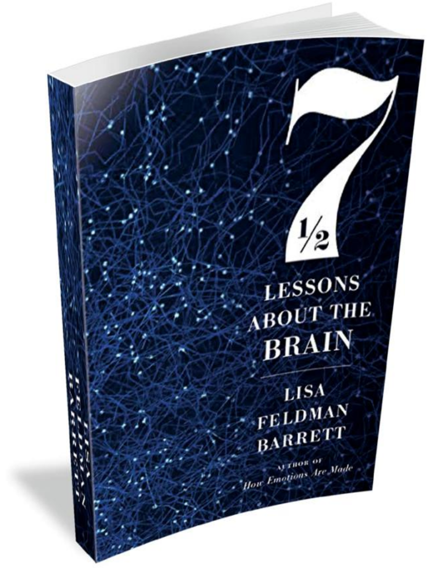
- Author: **Sarah Cruddas**
- Publisher: **HarperCollins UK**
- Price: **£16.99 (approx. $21.82)**
- Release: **Out now**

Throughout human history, our relationship with space has been one filled with wonderment, possibility and opportunity – aspects that Sarah Cruddas captures so well in her new book *Look Up*. What Cruddas has achieved with this book that most history books lack is a sense of human determination and our innate desire to explore during the years of blood, sweat and tears it took to venture to the Moon and beyond. From the famous Space Race and the missions that followed, Cruddas tells an old story with a fresh perspective.

She reflects on the history of space travel, the dedication and sacrifice – such as the astronauts who died in the devastating events of Apollo 1 – and looks to the future with a hopeful view. Posing questions about the ownership of space and even the possibilities of an 'off-world economy' for space-based companies, Cruddas remains level-headed about the possible challenges to come, both scientific and economic.

★★★★★





Seven and a Half Lessons About the Brain

Explore the world inside your head

- Author: **Lisa Feldman Barrett**
- Publisher: **Houghton Mifflin Harcourt**
- Price: **£18.33 / $24.00**
- Release: **17 November 2020**

The human brain is the only organ in our body that is capable of continuously learning about itself, and in reading this masterclass by renewed neuroscientist Lisa Feldman Barrett, it'll undoubtedly discover some new truths.

In seven-and-a-half fascinating lessons, Feldman Barret takes the reader on an in-depth journey through the workings of our brain and how it creates the world around us, while also demystifying some common misconceptions along the way. Although it's jam-packed with some hardcore neurological science, Feldman Barret cushions concepts with a light-hearted and sometimes humorous writing style.

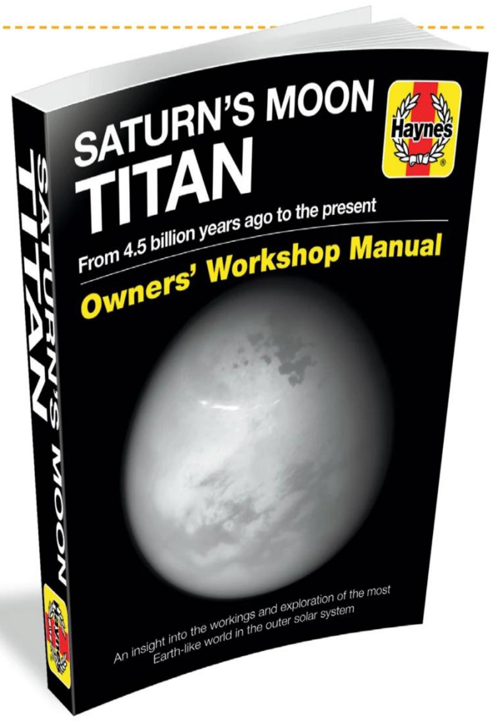
Whether you're looking to expand your knowledge about the little grey cells between your ears or you're a seasoned brain explorer, this book is an insightful and thought-provoking addition to your library.

★★★★★

Saturn's Moon Titan Owners' Workshop Manual

From 4.5 billion years ago to the present

- Author: **Ralph Lorenz**
- Publisher: **Haynes Publishing**
- Price: **£25.00 / $35.79**
- Release: **Out now**

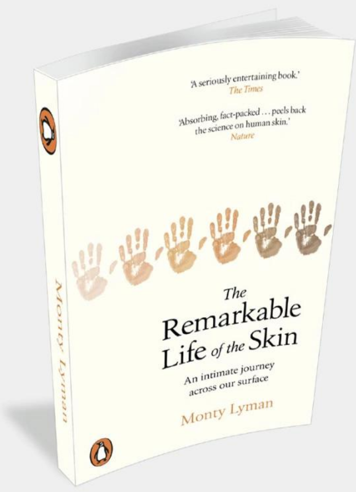


Titan may be a moon, but as this book will inform you, it could be mistaken for a planet. As Saturn's largest moon, it is bigger than Mercury, has its own atmosphere and its climate can be compared to those on some of the Solar System's terrestrial planets. As you navigate the pages of this book, you will journey through Titan's landscape, the science behind its atmosphere and much more.

While the large majority of the book relays information about the moon in an orderly and well-presented manner, it's not entirely focused on events of the past. The final chapter provides an air of science fiction, as the reader is given a taste of what could lie in the future and how Titan could become of great importance to the human race.

Having worked on the Cassini-Huygens mission, during which the Saturnian moon was studied in great detail, Lorenz shares his first-hand knowledge for all to understand. With vivid photography, informative diagrams and incredible facts, this manual serves as a thorough reference for all things Titan.

★★★★★



The Remarkable Life of the Skin

The physical, social and psychological impact of our largest organ

- Author: **Monty Lyman**
- Publisher: **Bantam Press**
- Price: **£20.00 / $27.00**
- Release: **Out now**

You might think you know your own skin pretty well. You see, touch and live in it every day, but the complexity of this organ is often overlooked. It can be our saviour as the body's barrier against infection, carry psychological significance, act as an indicator of a person's age and varies with genetics. It is something shared by all humans, and yet is so diverse.

Author Monty Lyman expertly explains how our outer body is constantly changing, how it has been viewed through history and the science that lies beyond our eyes' reach. From the skin's disturbing microscopic details to how a midnight snack could lead to sunburn, each varied chapter is filled with unexpected revelations. Skin can play a huge role in our identity, and with this fascinating book you can get to know your surface on a much deeper level.

★★★★★

The complexity of this organ is often overlooked

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

QUICKFIRE QUESTIONS

Q1 Which of these dinosaurs weighed up to 100 tonnes?
- Tyrannosaurus
- Brontosaurus
- Argentinosaurus
- Brazilosaurus

Q2 How long is a marathon exactly?
- 42,195mm
- 42,195cm
- 42,195m
- 42,195km

Q3 How fast does electricity travel?
- Half the speed of a bullet shot from a gun
- The speed of sound
- 1,000,000 kilometres per hour
- Nearly at light speed

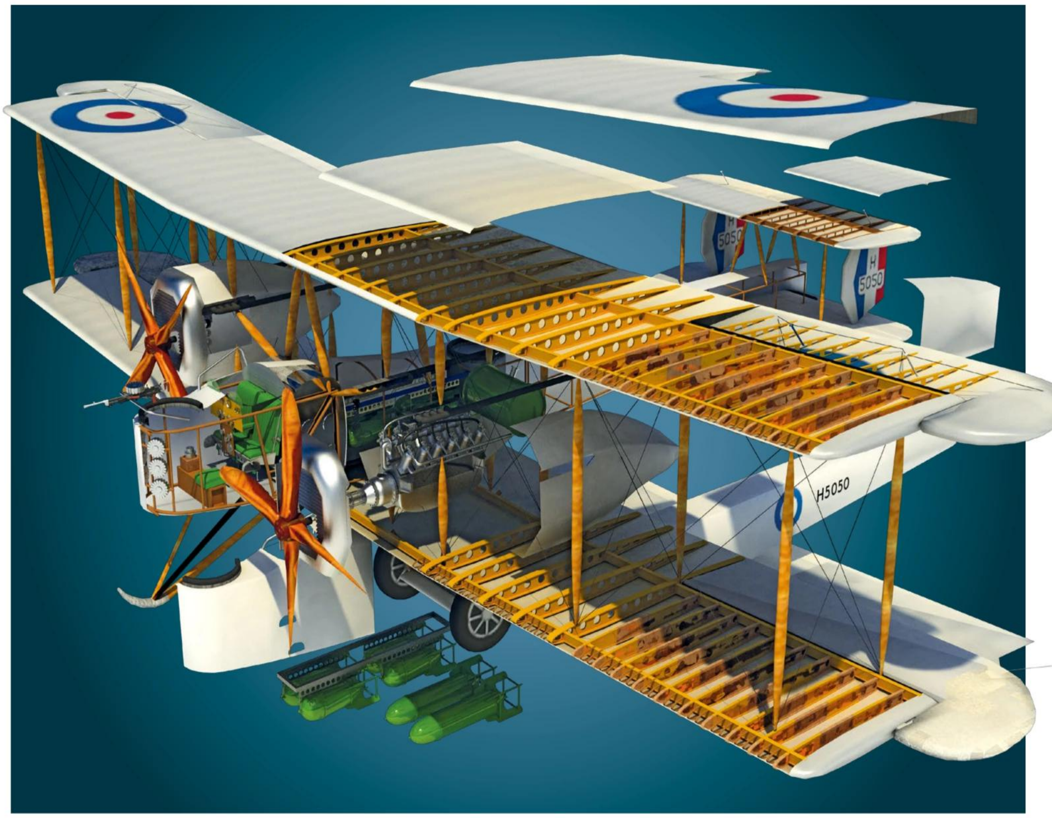
Q4 What's the average human lung capacity?
- 2 litres
- 6 litres
- 10 litres
- 12 litres

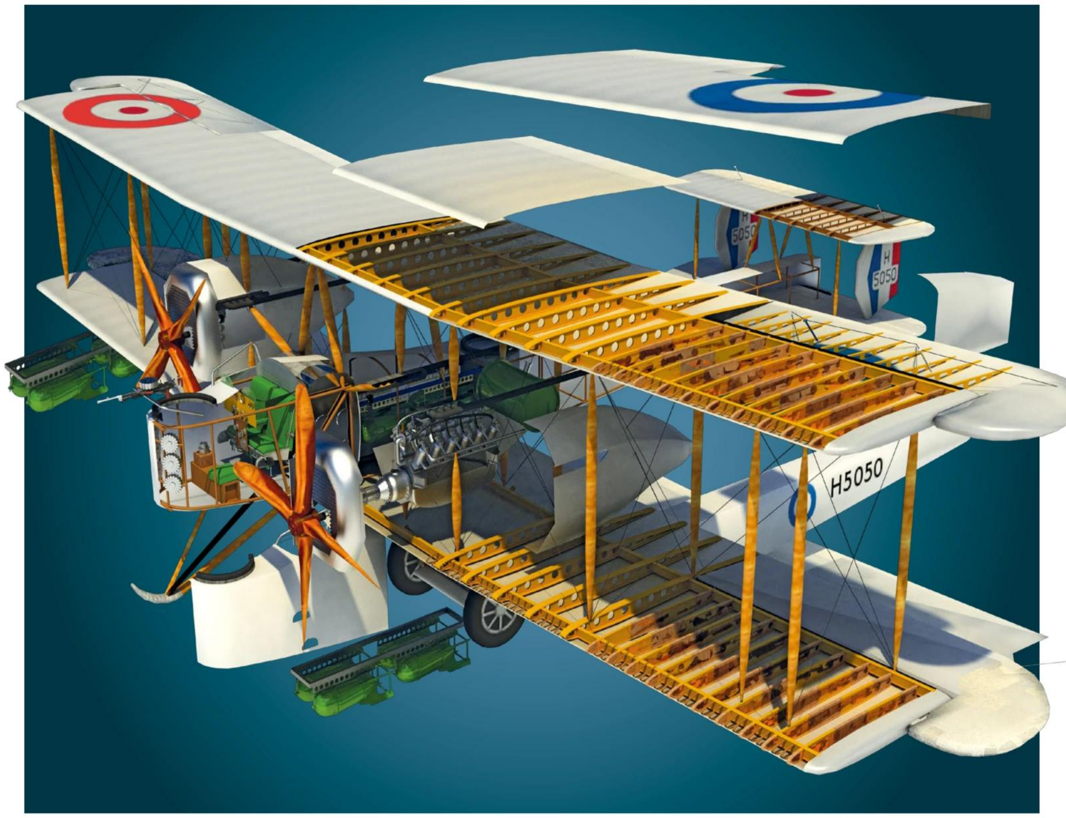
Q5 What element is used as a cathode in electric car batteries?
- Hydrogen
- Plutonium-239
- Gold
- Lithium

Q6 How long does Halley's Comet take to orbit the Sun?
- 923 years
- 33 weeks
- 66 years
- 75 years

Spot the difference

See if you can find all six changes between the images below





Sudoku

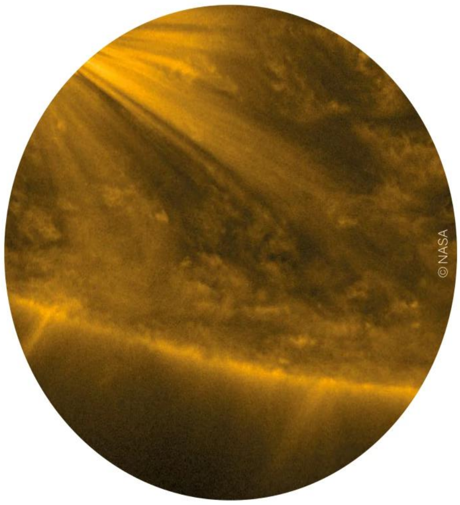
Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

9	8						6	5
5	4	3	8				9	
2						1	4	8
4			6				5	1
		2	3		8		7	9
6	9		1	5	2			3
	2							
		9	4		5	8		7
		5		6	3	9	2	4

DIFFICULT

				1		5		
5								
7	2						1	
				8				4
	3	5					2	7
	8	6					3	
		9	7		1			
			4	9	2	3	5	
		1	8			6		



What is it?

Hint: This sends more energy to Earth in an hour than humans use in a year...

A ....

T	E	S	L	O	N	E	S	O	A	T	E	L	S	I
E	Z	P	E	S	T	I	C	I	D	E	M	C	E	P
L	J	A	W	N	D	A	L	F	G	S	O	H	R	E
E	L	A	C	I	V	E	N	W	I	T	O	C	E	N
C	A	Q	U	E	G	O	L	D	Y	L	A	X	S	T
T	O	O	D	I	H	F	Y	T	E	R	A	P	P	A
R	C	B	A	T	I	O	S	S	E	J	N	M	I	D
I	K	S	A	R	U	N	F	O	S	S	I	L	R	R
C	O	R	I	S	P	U	T	N	I	K	N	T	A	I
O	A	D	E	T	A	J	D	E	C	K	O	P	T	T
M	E	B	R	I	G	O	L	B	K	Z	L	A	I	E
A	P	V	A	M	T	U	E	C	Y	C	N	I	O	N
G	O	D	L	B	E	N	H	U	E	R	O	X	N	G
I	E	R	O	N	J	A	W	S	H	E	L	S	I	A
N	I	G	S	I	N	T	O	K	E	T	Y	J	A	M

Wordsearch

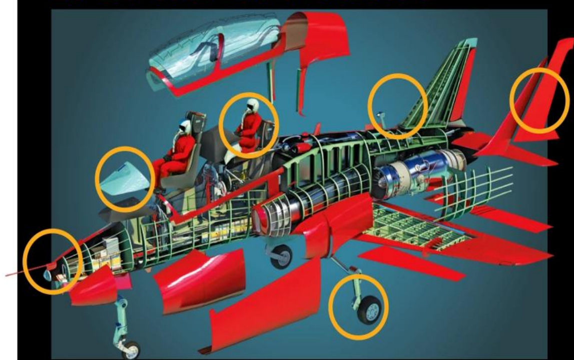
FIND THE FOLLOWING WORDS...

MAGNET
FOSSIL
MARATHON
PESTICIDE
JAWS
SOLAR
RESPIRATION
GOLD
ELECTRIC
SOCKET
TEST
SPUTNIK

Check your answers

Find the solutions to last issue's puzzle pages

SPOT THE DIFFERENCE



QUICKFIRE QUESTIONS

Q1 Typhoons
Q2 8
Q3 Sega Genesis
Q4 1924
Q5 Gold
Q6 The US nuked it

WHAT IS IT? ...MOSQUITO

HOW TO...

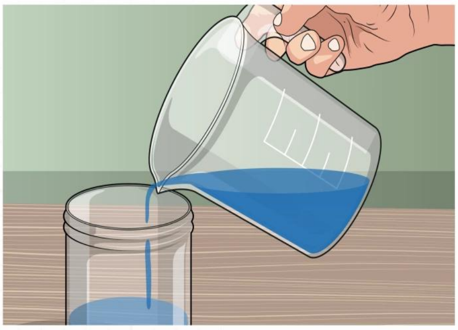
Practical projects to try at home

Get in touch
Send your ideas to...
How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

How to make a cloud in a jar

The sky is filled with water – this experiment will show you why

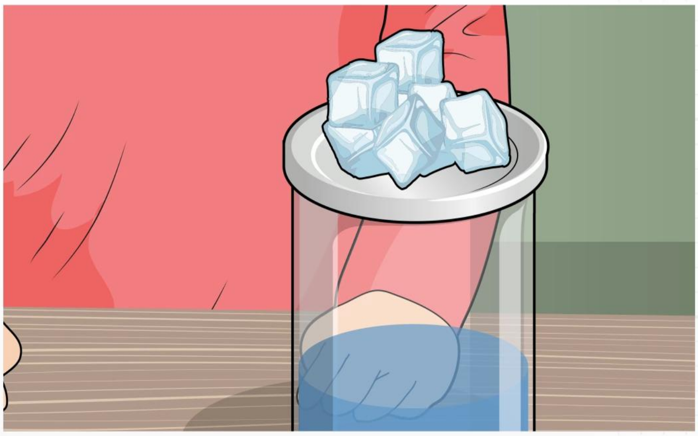
1 Collect your materials
For this experiment you will need a glass jar with a lid, one cup of hot water, some ice, hairspray and food colouring.



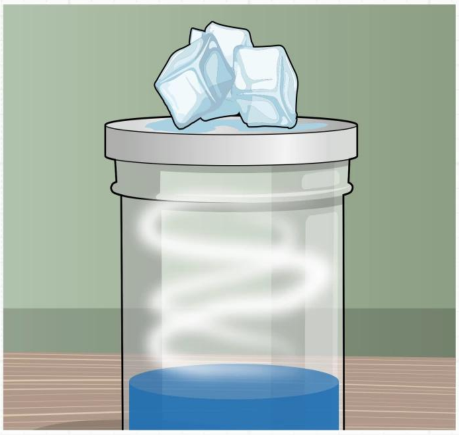
2 Make the base
Add a couple of drops of food colouring to the cup of water and pour it into the jar. Give the water a little swirl to warm the sides of the jar.

3 Add the spray
Take your can of hairspray and spray some into the jar. You will only need to spray for two to three seconds.

4 Seal the deal
As soon as you stop spraying, quickly fasten the lid onto the jar. Try to let as little of the aerosol escape as possible.



5 Cool the top
Place some ice cubes on top of the lid. Condensation will begin to appear in the form of a cloud.



6 Cloud creation
Continue watching the contents of the jar just above the water. You should see the cloud getting thicker and whiter.

7 Smooth escape
When the cloud is thick and white, remove the lid to release the contents. Watch how the cloud slowly creeps out of the jar.

SUMMARY
This cloud is created due to the contrasting temperatures at the jar's base and lid. When the warm water evaporates, it moves to the top of the jar. Here it comes into contact with air that has been cooled by the ice, forcing the water vapour to condense. Clouds form when there is a substance in the air for water to condense into, and in this case that is the hairspray. When you remove the lid, the hairspray escapes, carrying the water with it.

Had a go? Let us know!
If you've tried out any of our experiments – or conducted some of your own – then let us know! Share your photos or videos with us on social media.

NEXT ISSUE
How to make Halloween slime!

INBOX

Speak your mind...

Get in touch

If you have any questions or comments for us, send them to:

How It Works magazine @HowItWorksmag

howitworks@futurenet.com howitworksmag

Research shows different parts of the brain are used for maths and language

© Pixabay/Gerd Altmann

Numerical minds

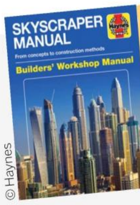
Dear **HIW,**

I love the space and science sections of your magazine, and I also really love maths. I see numbers and other things associated with maths as beautiful, but a lot of people who I know don't like numbers. I wanted to know why my brain sees maths as beautiful and why others see it in the opposite way.

Laila, 11

Maths is all about understanding patterns, and like yourself, some people take joy from finding these within numbers. The majority of people hold the ability to notice differences in quantities, but just as some people struggle with words and might show signs of dyslexia, other people's brains can have difficulty processing and understanding numbers.

People often like a subject more when they understand it better and can look into the details of it. Keep exploring the maths found in all areas of life and your love for it will only grow.



© Haynes

WIN!

WIN A HAYNES SKYSCRAPER MANUAL

Journey through the fascinating process of building a skyscraper, from initial concepts to the modern day. The Haynes *Skyscraper Manual* is fully illustrated with stunning photographs and technical drawings.

Letter of the month

Pentadiamond strength

Dear **HIW,**

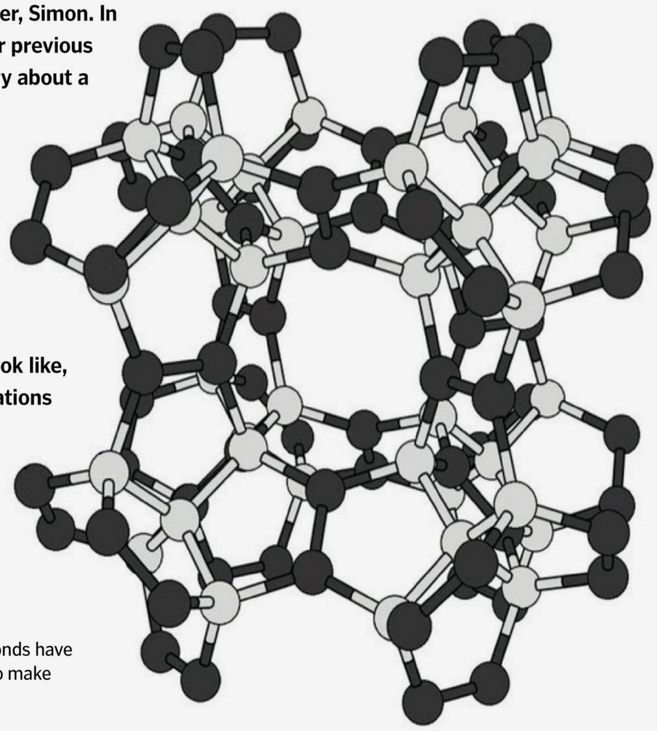
Great magazine – absolutely love it and have all issues to date. I've just read issue 142's article on pentadiamonds and wondered what the pentagon lattice might look like, as the image you supplied is essentially just hexagons. Your article mentions a computer model of a football with several smaller footballs around it. Could you please include an image in your next issue?

Simon Mehlman

Thank you for your letter, Simon. In the news section of our previous issue, we shared a story about a potential new carbon arrangement that is harder than a diamond and could be used as a material for electricity conduction. This image shows further details of what the pentadiamond could look like, using computer calculations from the University of Tsukuba.

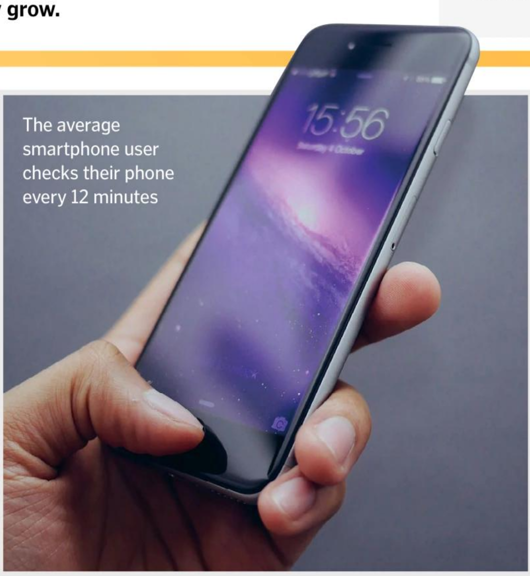
The team calculated this maze of carbon by using a density functional theory. This involves analysing the shape and properties of the materials used to predict how it would compare with other materials. The system has been shown to create accurate results.

When holding this pentadiamond in your hand, it would feel lighter than a normal diamond. With its strength and weight, it could upgrade materials used in race car manufacturing. However, until it is created, this structure remains theoretical.



The carbon atoms in diamonds have been rearranged in order to make them harder and lighter

© University of Tsukuba



The average smartphone user checks their phone every 12 minutes

© Pixabay / Fancycrave1

The love of smartphones

Dear **HIW,**

I was just watching my parents and thinking: "Why are people so addicted to their phones?" Every time I watch my parents, they just whip out their phones.

How do people become addicted to things this easily?

Yixin Luo, aged 10

This is a great observation, Yixin, and demonstrates an addiction that the majority of adults share today. There is so much we can do with our mobile phones, from socialising with friends to navigating the streets. The internet is a quick tool for answering our questions and games can relieve us of boredom. Through these uses, many of which are keeping us connected, our brains release dopamine – a feel-good chemical.

As the body recognises that connecting to social media through our phones rewards it with chemicals, we begin to look more frequently for our next hit of dopamine until the act of checking our phones becomes a deep-rooted habit.

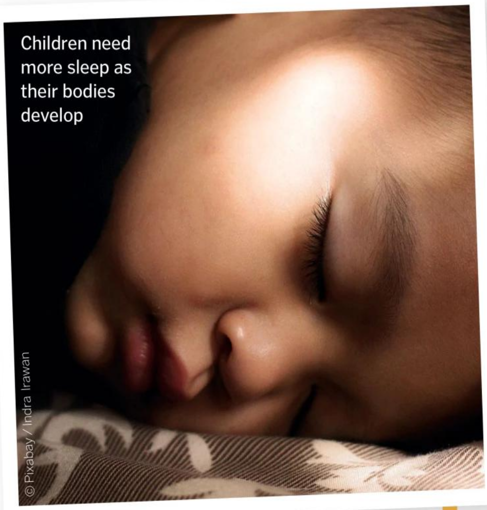
Sleepy species

■ Dear **HIW,**

Humans seem to need a lot of sleep. Why do we need eight hours or more a night rather than just two or less?

Stephen

Eight hours might seem like a long time to be unconscious, but humans actually sleep less than most primates. In general, smaller animals have higher rates of brain metabolism and need longer sleeps, while larger animals require less. We need enough time for our brain to process information and store memories.



Children need more sleep as their bodies develop

© Pixabay / Indra Irawan

Old news

■ Dear **HIW,**

I have been checking the news a lot recently, and it got me thinking about how we all rely on it to know what is going on in the world. How did the news first come about?

Ellie Gordon

Great question. Humans love to share stories, and this has been documented throughout history. News would have originated as messengers travelling to tell communities of battles and events that had taken place. However, the reliability could be questioned due to its spoken nature. These stories soon moved on to written documents of events during Roman times, which would be put up in public places. Mass printed media, however, was first made possible with the invention of a letterpress in 1450.

© Pixabay/Stocksnap

England's first newspaper was made in 1665

What's happening on... social media?

This month we asked you: 'If you could travel back to the time of the dinosaurs, which species would you most want to see and why?'

@GrumFromNorwich
One that no one else knew about. You step from the time vortex and it's Triceratops, Tyrannosaur, Pteradon and what-is-that…

@scimaxfacts
Suzhousaurus. It looks so unusual compared to modern-day animals that we know today

@olb_ken0bi.rl
Velociraptor because I'd like to see them use their incredible skills in the wild

@jeanmcdougall8333
T. rex the biggest

@danielj868
A pterodactyl, it was big and flew

@maia_h3
Maiasaura as it shares my name!

NEXT ISSUE…

Issue 144 on sale **29 OCT 2020**

Available in print from all good newsagents and **magazinesdirect.com**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 18 (UK) and 53 (US).

HOW IT WORKS

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Editor **Ben Biggs**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Nikole Robinson**
Staff Writer **Scott Dutfield**
Staff Writer **Ailsa Harvey**
Editor-in-Chief **Gemma Lavender**

Cover images
Getty; Honda; Meade

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Wikimedia
All copyrights and trademarks are recognised and respected

Advertising
Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Senior Advertising Manager **Amanda Burns**
amanda.burns@futurenet.com
0330 390 6036
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
+44 020 3970 4176

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
Head of Print Licensing **Rachel Shaw**
licensing@futurenet.com

Subscriptions
Enquiries **help@magazinesdirect.com**
UK orderline & enquiries **0330 333 1113**
Overseas order line & enquiries **+44 (0)330 333 1113**
Online orders & enquiries **www.magazinesdirect.com**
CRM Director **Louise Dudfield**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Vivienne Calvert**

Management
Brand Director **Evan Kypreos**
Chief Content Officer **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Head of Art & Design **Greg Whittaker**

Printed by William Gibbons & Sons Limited
26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
www.marketforce.co.uk
Tel: 0203 787 9001

ISSN 2041-7322

FUTURE
Connectors. Creators. Experience Makers.

Future plc is a public company quoted on the London Stock Exchange (symbol: FUTR)
www.futureplc.com

Chief executive **Zillah Byng-Thorne**
Non-executive chairman **Richard Huntingford**
Chief financial officer **Rachel Addison**

Tel +44 (0)1225 442 244

FAST FACTS

Amazing trivia to blow your mind

45,000

MANY RUNNERS WERE DISAPPOINTED BY THE CANCELLATION OF THE 2020 LONDON MARATHON

60 TONNES

NAMIBIA'S HOBA IS THE WORLD'S HEAVIEST RECORDED METEORITE, FOUND IN 1920

17cm

THE MAN WITH THE WORLD'S WIDEST JAWS CAN FIT A WHOLE DRINK CAN IN HIS MOUTH

2100

VENICE COULD BE COMPLETELY UNDERWATER IN LESS THAN A CENTURY

1963

FRANCE SENT THE FIRST CAT INTO SPACE NEARLY 60 YEARS AGO

FOSSILISED DINOSAUR FEATHERS WERE FOUND IN AUSTRALIA IN 2019

'OUMUAMUA IS THE FIRST RECORDED OBJECT TO VISIT FROM ANOTHER STAR SYSTEM

3,000,000 VOLTS

A LIGHTNING BOLT CAN MEASURE OVER 10,000 TIMES THE VOLTAGE OF A HOUSEHOLD ELECTRIC OUTLET

2.3 SECONDS

TESLA'S MODEL S E-CAR CAN ACCELERATE FROM 0 TO 60 IN RECORD TIME

1902

THE ROCKY MOUNTAIN LOCUST BECAME EXTINCT IN THE US OVER 100 YEARS AGO

SOLAR POWER IS BY FAR THE MOST ABUNDANT ENERGY SOURCE IN THE WORLD

KING & COUNTRY
UK AUTHORISED DEALER

JN061 *Kenpeitai Officer (Single figure)*

JN062 *'BANZAI!' Set#1 (3 fig. set)*

JN063 *'The Mortar Set' (2 fig. set)*

JN-S03 *Captor & Captured! (2 figure set)*

JN064 *The 'Kamikaze' Tank Bomber*

Knights of Bushido

During WW2, *'BUSHIDO'*, originally an ancient *Samurai* code of honour dedicated to their way of life and concept of chivalry was transformed into Imperial Japan's cruel and violent way to wage war on enemy soldiers and civilians.

Japanese soldiers were indoctrinated with the belief that to die for the Emperor was their greatest honour... and to be captured was their worst shame.

Allied soldiers who surrendered to the Japanese – regardless of their courage in battle were seen to be beneath contempt and suffered accordingly. In Japanese eyes *'No quarter was asked... and none was given'*.

Here are latest King & Country *Japanese infantry in action,* alongwith some senior officers and a member of the infamous *Kenpeitai* Military Police.

JN060 *Japanese Command Set*

USMC053 *The U.S.M.C. Pacific Sherman*

JN064

There's also a brand-new *'Type 92'* light tank as well as our existing *'Type 95'*.

Although all-conquering at the beginning of the Pacific War the Imperial Japanese Army was soon to meet their match when the Allies went on the offensive.

For more details about these dramatic new releases go to *King & Country* or MAGPIE.

MAGPIE are the largest UK Dealer for King & Country products and we supply collectors not only in the UK... but all over the world!

JN059 *'Type 92' Light Armoured Tank*

JN041 *"Type 95 'Ha-Go Light Tank" (2nd Version)*

MAGPIE (MANCHESTER HOUSE) LTD

KING & COUNTRY HEADQUARTERS
Suite 2301, 23rd Floor, No.3 Lockhart Road,
Wanchai, Hong Kong
Tel: (852) 2861 3450
E-mail: sales@kingandcountry.com

MAGPIE OPENING TIMES
DAILY 9:00AM - 5:30PM
CLOSED WEDNESDAY & SUNDAY

MAGPIE
1 High Street, Evesham
Worcestershire, WR11 4DA. England UK
Tel: 01386 41631
eBay shop: Manchester House Collectables
Email: magpie2500@aol.com

STARTER SETS: WHAT'S ON THE BOX?

Every Airfix Starter Set box contains a wealth of information to help you choose the best kit and achieve the best finish.

1. History
A small piece of history is included on the top of each Airfix kit box. This gives some background information of the product, including actions the real item was involved in. The area also shows the dimensions of the finished model and the number of pieces.

2. Flying hours
Become a member of the Airfix Club and you can collect the Flying Hours to receive FREE model kits. The bigger the kit, the more Flying Hours are available to accumulate.

3. Skill level
The skill level, from 1 to 4, explains how difficult the model will be. A higher skill level kit often has more parts and is more challenging to build.

4. Paints, Cement and brushs
Everyting to build a finished model is included, including model cement, paint brushes and acrylic paints. The Humbrol™ products will enable you to create the best finish for your model.

5. Scheme
The scheme is outlined on the top of the box with the markings and descriptions.

6. Decals
The side profile on the front shows the position of the decals to give you a clear idea what the final model will look like.

7. Product code
The product code is unique to each kit. It helps you to identify your kit of choice easily, assists with navigating through the catalogue or Airfix website accurately, determines the size of the kit and gives guidance to the number of parts.

8. Model scales
The scale of the kit indicates how large the model will be in relation to the full size vehicle. All of the aviation Starter Sets are 1:72 scale, therefore the model is 72x smaller than the original (1:32 = 32x smaller). The smaller the scale number – e.g. 1:24 = the larger the kit compared to the original. All of the automotive Starter Sets are 1:32 and the tanks are 1:76.